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ANOTHER TRANSCONTINENTAL RAILWAY LINE is to be built in Canada, according to a published announcement of Grand Trunk Railway officials. It is said that the Grand Trunk system will be extended from North Bay or Gravenhurst, Ont., westward to the Pacific coast, a distance of nearly 3,000 miles. The governing motive for the extension is the remarkable development of Manitoba and British Columbia which has taken place during the past few years. The Pacific terminus will be at Butte Inlet or Port Simpson, B. C. The extension is to be built under the name of the Grand Trunk Pacific Ry. Co.

A RECORD FOR RAPID FREIGHT MOVING on the Pennsylvania R. R. at Pittsburg was established on Sunday and Monday of this week. After 36 hours of unceasing labor, 929 trains, consisting of 46,225 cars, were moved in and out of Pittsburg, with an estimated tonnage of 1,756,550. Due to the fact that a large number of green hands were employed, eight men were more or less seriously injured during the first 24 hours. The congestion of freight is only partially relieved by this action, and it will be weeks before a normal condition again exists.

PRIZES FOR PAPERS ON RAILWAYS are offered by the Pacific Coast Railway Club. The competition, which is open to members of any railway club in the United States, is defined as follows: "For papers pertaining to the construction, equipping, maintaining and management of steam railways, the papers to contain not less than 2,000 nor more than 6,000 words. The prizes will not be awarded from a literary standpoint, but according to their intrinsic value to the railway world." Papers should be sent to the secretary of the club, Mr. C. C. Borton, 1213 Twelfth St., Oakland, Cal., and must reach him on or before Jan. 1, 1903. The prizes will be awarded by five judges, to be selected from leading railway officials of the Pacific Coast. Four prizes aggregating $250 are offered, this amount being divided into sums of $100, $75, $50 and $25.

WOODEN STATION PLATFORMS are to be abolished on the Chicago & Alton Ry., and replaced by concrete platforms. The new platforms will be not only more cleanly and more durable, but will not be as exposed to risk of fire, and will cost very little more than the wooden ones.

THE BERLIN-ZOSSEN HIGH-SPEED experimental electric line, in Germany, has been the subject of some further experiments recently. The Siemens-Halske Co., of Berlin, built an electric locomotive equipped with three-phase induction motors, operating with the full line-pressure of 10,000 volts on the motors. With this locomotive speeds of 75 miles per hour were attained, and were found to be perfectly safe as regards both roadbed and locomotive.

THE MARKING OF RAILWAY TIES is an important feature of any method for keeping accurate records of the life and efficiency of ties, and a circular has been issued by the Railway Engineering & Maintenance-of-Way Association calling the attention of the managing officers of railways to the system of marking advocated in the last report of the Committee on Ties. The plan proposed is similar to that adopted by the U. S. Department of Agriculture in a section of experimental track laid in Texas, and briefly described is as follows: Each tie is marked with a dating nail; this is placed between the rails on top of the tie, generally at a specified distance from the rail. The nails are of steel, covered with zinc or tin, and have the year stamped in the head. When renewals take place, the date at which each tie was laid is noted, and in this way an absolutely reliable record is obtained. The nails cost very little (about 6 cts. per lb., 30 nails), and when put in by the section gang, the labor is very slight. Several American railways are stated to have already adopted this plan. Accurate statistical information in regard to the life of treated and untreated ties, a comparison of the different kinds of wood used for ties under varying conditions of soil and climate, etc., is essential to the proper study of the tie question. For the purpose of making information of this character available and presenting it from year to year, a series of blank forms, prepared by the Committee on Ties, has been adopted by the Association as standard, and it is suggested that each road take the necessary steps at once to inaugurate the system of keeping tie records in the manner proposed by the committee. The blanks may be obtained on application from the Secretary, Mr. L. C. Fritch, 1562 Monadnock Block, Chicago, Ill.

THE MOST SERIOUS RAILWAY ACCIDENT of the week occurred on the New York, New Haven & Hartford R. R., near Madison, Conn., on Nov. 18. A fast freight train parted, and later the two sections collided. The train was partly wrecked and one man was killed.—In a collision between a passenger train and a freight train at Summit Station, N. Y., on the Buffalo, Rochester & Pittsburg Ry., on Nov. 20, one man was killed and several others injured. The freight had run into a turnout to let the other train pass, but the momentum carried the train too far, so that the engine ran out on to the main line just as the passenger train came along.

TWO FATAL BOILER EXPLOSIONS occurred within the last few weeks. On Nov. 9 a boiler in one of the pumping stations for the Borough of Brooklyn, New York city, blew up, wrecking the station and killing two men, the engineer and fireman of the plant. The station pumped water from wells, and this water was used in the boilers. The water is very hard, and, it is claimed, has long been known to be very injurious to boilers. The other explosion occurred on Nov. 13 at the works of the American Iron & Steel Mfg. Co. The boiler was part of a puddle-furnace plant, and its explosion wrecked the entire plant, including nine furnaces. Ten men were killed in the explosion and the resulting destruction of the plant.

GREAT HAVOC FROM VOLCANIC ERUPTIONS is reported from Guatemala, Central America. The volcano of Santa Maria, in the northwest part of the country, broke out violently on Oct. 24, and continued in eruption for a number of days. The region around for a distance of 30 to 40 miles was laid waste and buried under a deep layer of ashes. No exact information as to either the loss of life or the property damage are obtainable. Estimates of the number killed range from 2,000 to 5,000. It will be recalled that the Guatemalan volcanoes were reported active early last spring, before the disasters in the Windward Islands, and that some time later an earthquake-like disturbance destroyed a town in San Salvador, just to the south of Guatemala.

THE CONSTRUCTION OF AN AMERICAN PACIFIC cable is now assured. The company which will lay the cable is to use the soundings made by the government some years ago. The line will run from some point in California to Manila, in the Philippine Islands, via the Hawaiian Islands, the Midway Islands, and Guam. From Guam two links will extend, one to Manila and the other to China. The cable will be subject to the control of the United States in time of war.

WATER SUFFICIENT TO DEVELOP 100,000 HP. was successfully sent through the tunnel tailrace of the Niagara Falls Power Co., at Niagara Falls, N. Y., on Nov. 19. This was done in advance of the completion of the new installation of 55,000 HP., making 105,000 in all, as a test of the capacity of the tailrace. The test lasted from 10 a. m. to 5 p. m., and during all but one hour of this period water from the 8,000-HP. wheels of the International Power Co. was being discharged into the main tailrace through a branch tunnel. The discharge from the main tailrace formed a current reaching across the river to the Canadian shore. Among others present at the test were Mr. Clemens Herschel, M. Am. Soc. C. E., Consulting Engineer, and Mr. Wm. A. Brackenridge, M. Am. Soc. C. E., Engineer of the Niagara Falls Power Co.

A HIGH MASONRY DAM is being built as a part of the water supply development of the Denver Union Water Co., as a substitute, as we understand it, for the proposed steel-faced rock-fill dam, 210 ft. in height, which was injured by a flood on May 3, 1900, as described and illustrated in our issue of May 17, 1900. The masonry dam now under construction is being built by the South Platte Canal & Reservoir Co., with Mr. Alex. E. Kastl, M. Am. Soc. C. E., of Denver, as Chief Engineer. We are indebted to Mr. Kastl for the following notes regarding the dam:

The height of the dam from the river bed to the crest will be 223 ft.; from the lowest point in the foundation to the crest, 232 ft. By the end of November the dam will be built to within 50 ft. of the crest. It is expected to be finished the latter part of 1903. The dam is 176 ft. wide at the base, and will be 18 ft. wide at the crest. Its length across the stream at the base is about 30 ft., and at its crest will be about 670 ft. It is curved in plan, the radius of the up-stream face at the crest being 400 ft. The masonry is granite rubble, laid in 2½ to 1 Portland cement mortar, except the up-stream face, which is granite ashlar laid in 2 to 1 Portland cement mortar. The water is to be drawn from the reservoir through three tunnels, the entrances of which are 107 ft., 157 ft. and 207 ft., respectively, below the crest of the dam. These three tunnels unite into one tunnel 7 × 9 ft. in cross-section. All the tunnels are driven through solid granite rock near the northerly end of the dam. The flow of water through the tunnels is controlled by valves. A spillway with its crest 5 ft. below the crest of the dam will be constructed in a natural saddle or depression of the granite ridge northerly of the northerly end of the dam. The length of the spillway has not been finally decided upon. It will not be less than 250 ft. long, and may be made longer. A 250-ft. spillway, with 2 ft. of water on its crest, will discharge about 2,200 cu. ft. of water per sec., which is more than the greatest known flood. On the construction of this dam Mr. Charles L. Harrison, M. Am. Soc. C. E., was Chief Engineer until May 24, 1902. Mr. Alexander E. Kastl, M. Am. Soc. C. E., has been Chief Engineer since May 15, 1902. Mr. J. E. Maloney was Resident Engineer until April, 1902. Mr. F. C. Horn has been Resident Engineer since April, 1902. Mr. Lyman E. Cooley, M. Am. Soc. C. E., and Mr. Alfred Noble, M. Am. Soc. C. E., both of Chicago, have been the Consulting Engineers.

BIDS FOR ABOUT 96 MILES OF SEWERS at New Orleans, La., will be received on Feb. 23, 1903. The work will include about seven miles of 72 to 27-in. brick or concrete sewer, 10 to 24 ft. deep, and 89 miles of 36 to 8-in. pipe sewer, 5 to 20 ft. deep. There will be some 1,100 manholes and 450 flushtanks. The work will be divided into eight sections, thus giving an opportunity to small contractors who do not wish to figure on the whole system. After Dec. 15 plans and specifications may be seen at the office of Hering & Fuller, Consulting Engineers, 170 Broadway, New York city. Mr. Geo. G. Earle is General Superintendent of the New Orleans Sewerage and Water Board.

AN UNDERGROUND PUBLIC WATER CLOSET at San Francisco is to be built and presented to the city and county by the Merchants' Association of San Francisco. It will be located beneath the sidewalk of Stockton St., adjacent to Union Square, with entrances from the square or park, and will cost about $5,000. There will be compartments for men and for women, and it is intended to make the station a model in every respect. It will be the first station of the kind in San Francisco, and probably the first one on the Pacific Coast. The park commissioners have voted to maintain the station, and contracts will be let as soon as possible. A plan and sections of the station are given in the Merchants' Association "Review" for November, copies of which may be obtained from Mr. L. M. King, Secretary, Mills Building, San Francisco, Cal.

A BOLLMAN TRUSS RAILWAY BRIDGE IN SERVICE FROM 1862 TO 1902.

The accompanying cuts represent an iron railway bridge of 120-ft. span, which was built in 1862, and is still in existence, but on its third site. For the photographs we are indebted to Mr. W. L. Breckenridge, Chief Engineer of the Chicago, Burlington & Quincy R. R., who sends us the following communication:

Sir: I send you two photographs which may be of interest. They show an iron bridge now in service which has the following record: It was built under Wendel Bollman's patents in 1862 by Charles Kellogg & Co., of Detroit. I cannot ascertain in what year it was erected, but it was taken out of the main line of the Chicago, Burlington & Quincy R. R. in 1880, and placed on a branch line. In 1890 it was taken out of the branch line and sold to another railway, where it now stands. I shall be glad to know whether or not this is a remarkably long life for an iron railway bridge.

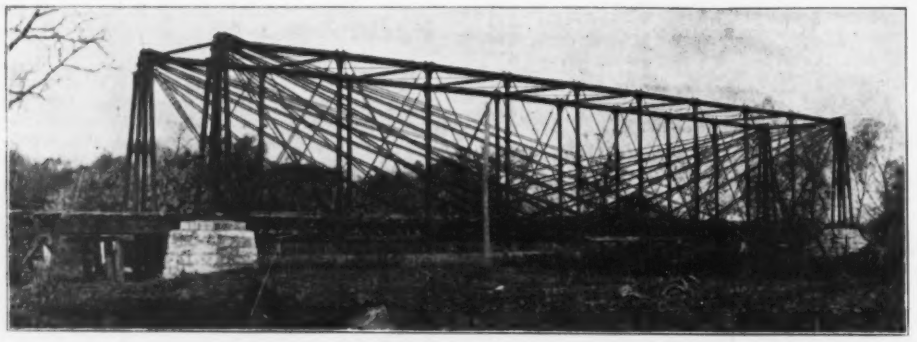


FIG. 1. BOLLMAN TRUSS IRON RAILWAY BRIDGE NOW IN SERVICE (1862-1902); 120-FT. SPAN.

This bridge has undoubtedly had a remarkably long life, 40 years, and its existence is no doubt due to the fact, that it was well built in the first place, and has been removed to a line of light traffic and equipment, where the loads are not greatly in excess of those for which it was designed. In the paper on "Unit Stresses and Impact in Old Railway Bridges," in our issue of Sept. 25, it was stated that the life of the best-designed metal bridges, when not overloaded, will seldom exceed 60 or 80 years, but the average life of metal railway bridges in this country has not been more than 20 years, chiefly on account of the steady and comparatively rapid increase in rolling loads.

THE COST OF HYDRAULIC EXCAVATION FOR EMBANKMENTS AND FOR PLACER MINING.

To California gold miners and mining engineers the world is indebted for the development of the cheapest means known for moving earth. Engineers in general are apparently strangers to the great economy of the hydraulic method of excavation, or if not ignorant of its economic merits as applied in California, they hesitate to use the method elsewhere. However, there is nothing mysterious or difficult about the hydraulic method of earth excavation, nor does it always require so great an expenditure for plant as to put it beyond the reach of those contemplating excavations of any considerable size. It is generally assumed that there must be a gravity supply of water, but even this condition is not essential to economic excavation and transportation of earth, as we shall presently see.

At the November, 1901, meeting of the American Institute of Mining Engineers, Mr. William H. Radford, of San Francisco, read a paper entitled "Notes on Hydraulic Mining in Low-Grade Gravel," wherein are contained data valuable to civil and mining engineers alike. A ditch 11 miles long delivered water to the "giant," as the huge nozzle is termed. Two men during the rainy season and one man during the dry season cared for the ditch. Water was purchased for 0.69, or practically 7-10-ct., per miner's inch of 1,728 cu. ft. per 24 hours. During the season from November, 1899, to the last of July, 1900, 655,657 miner's inches washed down, by actual survey, 1,251,399 cu. yds. of gravel, or 1.91 cu. yds. of gravel per miner's inch. From this we see that 906 cu. ft. (= 33½ cu. yds.) of water were required to move each cubic yard of gravel, which gives a good ratio upon which to base estimates of the cost of hydraulic excavation.

The gravel was partly washed from the river bed to a depth of 1 to 8 ft., until bed rock was reached (7,134 acres bedrock uncovered), but a large part was washed from the mountain side by attacking a face 50 to 130 ft. in height, averaging 63 ft.

Long cuts or rock ditches were excavated in the slate bedrock into which the gravel was washed when cleaning off the bedrock. The total cost of moving this gravel was only 2½ cts. per cu. yd., itemized as follows:

Cost of Hydraulic Excavation.
(1,251,400 cu. yds. gravel.)

Care of ditches and reservoir, labor	$2,670.99
Care of ditches and reservoir, supplies	115.55
Washing (piping)	2,401 05
Drilling bedrock ditches by hand	1,050.91
Drilling bedrock ditches by electric drill	269.62
Timbering rock ditches	157.39
Electric lights	598.62
Building sluices and repairs, labor	1,045.70
Building sluices and repairs, supplies	35.50
Blacksmithing	644.02
Cleaning-up gold	968.79
Moving pipes and "giants"	898.85
Breaking rocks and clay	6,124.91
Cutting brush (for piping)	158.37
General expenses and watching sluices	3,088.69
Supplies	3,015.37
Taxes, office and legal expenses, surveying, salaries	4,267.31
Total	$27,511.64

If we deduct such items as pertained only to the recovery of the gold we find that the actual cost was 2 cts. per cu. yd. of gravel moved. This estimate includes no charge for interest and depreciation of plant, which is obviously an item of extreme variation.

Fig. 2. End View of Bollman Truss Bridge.

The gold recovered by amalgamation was $31,618.49, leaving a profit of but $4,100 for the season, which is exceptionally low.

The wooden sluices had a 5% grade and were of course water-tight, since any leakage would cause loss of amalgam; but in cases where gold is not to be recovered from the material much cheaper sluices of rough lumber can evidently be used.

Mr. Latham Anderson, in a paper published in the 1901 volume of the Association of Engineering Societies, gives some abstracts from the United States Geological Survey Report, 1897, Part IV., which we can here repeat to advantage in illustrating what has already been done in the way of economic earth excavation.

HYDRAULIC FILLS ON THE NORTHERN PACIFIC R. R.

During 1897, in eight high trestles, 377,000 cu. yds. were moved for about 4.8 cts. cu. yd.

Sluicing and building side levees	[illegible]
Hay used in levees	[illegible]
Tools	[illegible]
Lumber and nails	[illegible]
Labor building flumes	[illegible]
Engineering and superintendence	[illegible]
Total cost per cu. yd.	[illegible]

In the above work water was carried by gravity. In one case pumping was resorted to, and 42,250 cu. yds. were moved for 13½ cts. cu. yd. The plant was inexpensive. One No. 2 "giant" costing $95, with 300 to 1,000 ft. of light sheet-iron pipe costing 27½ cts. per foot, and lumber for sluices, which may be re-used in moving from place to place, constituted the outfit. Five to six men were required to erect and operate the plant.

HYDRAULIC FILLS ON CANADIAN PACIFIC R. R.

(See also Eng. News, Nov. 28, 1895.)

Trestle No. 374, in Frazer River Canyon, 231 ft. extreme height, was filled at the rate of 750 cu. yds. per day, with 148,000 cu. yds., at a cost of $5,089, or 7¼ cts. per cu. yd., including cost of plant, explosives used on cemented gravel, labor, etc. Fifty per cent was cemented gravel, 30% loose gravel and 20% large boulders, which were removed with a derrick. The plant consisted of 1,450 ft. of sheet steel 15-in. pipe, 1,200 ft. of sluices or flumes, 3 ft. wide × 3 ft. deep; one No. 3 "giant" monitor with 5-in. nozzle, and a large derrick driven by a Pelton water wheel to handle boulders. Piping head was 125 ft. Sluice boxes were laid on 11 to 25% grades, partly supported on high trestles. The sluices were paved with wood blocks on the light grades, and old railway rails on the heaviest to protect them from abrasion. The entire force of 7 men, except the pipeman, were common laborers, working as follows: One man at "giant," one at head of sluice, two along sluice keeping large stones moving, three at outlet of sluice directing stream, and building small retaining barriers of brush or old ties. The water used was 20 second-feet or 1,000 miner's inches, the duty performed being 1.77 cu. yds. gravel moved per 24-hr.-inch, which is equivalent to about 980 cu. ft. of water per cu. yd. excavated, but it was claimed that if the head had been about 400 to 500 ft. and the gravel all loose, "the duty of the water would have been increased fourfold." Note, however, that amount of water actually used agrees closely with Mr. Radford's placer mining experience above given.

At Chapman's Creek the company made a similar fill of 66,000 cu. yds., for which the labor cost was $2,862, or 4.34 cts. cu. yd., and estimating 20% of the cost of plant as chargeable to this job, the total cost was $4,715, or 7.15 cts. cu. yd. The actual work of sluicing after the plant and sluices were in place was 1.78 cts. cu. yd., hence the labor of erecting the plant must have been 2.56 cts. cu. yd.

DAM AT TYLER, TEXAS.

This earth dam was built in 1894 by the hydraulic method. The embankment is 32 ft. high, 575 ft. long, and contains 24,000 cu. yds. The water for hydraulicking was pumped through a 6-in. pipe from the city pumping station. The water jet was directed by an ordinary 1½-in. nozzle attached to a 2½-in. hose, and the pressure was 100 lbs. per sq. in.

The washing was carried into the hill on a 3% grade, which soon gave a 10-ft. face, increasing gradually to a 36-ft. face. The jet, of course, was directed at the foot of the face, undermining the material. The cost, including plant, labor, etc., was 4¾ cts. per cu. yd. excavated.

THE SAN LEANDRO DAM (CAL.).

This dam, built in 1874-5, contains 542,700 cu. yds., of which 160,000 cu. yds. were deposited by the hydraulic method at a cost of ¼ to 1-5th the cost of moving earth by carts or scrapers. The water was brought four miles in a ditch, and

the sluiced gravel was conveyed in a flume lined with sheet iron, laid on a 4 to 6% grade.

To the engineer, the most important data relative to hydraulic excavation are results of actual practice, showing the number of cubic yards of material excavated by a cubic foot of water. The most complete information that we can find on this subject is given in a paper on "Hydraulic Mining in California," read by Mr. A. J. Bowie, Jr., in 1877, before the American Institute of Mining Engineers. From this paper, which goes into great detail, we have condensed and tabulated the accompanying Table I., which is based upon actual measurements and is reliable.

The foregoing indicates about the maximum cost of hydraulic excavation on a large scale, for the banks were not very high, the head of water was low, and the flumes were laid on a very gentle grade—all of which factors increase the consumption of water, as is well shown by comparison with Table II..

We see from Tables I. and II. that the cubic feet of water required to move each cubic yard of gravel may be from 450 to 2,000; and that the cost of labor alone may be 1¼ to 4¼ cts. per cu. yd. It appears that ordinarily about 1,000 cu. ft. of water are required to loosen and move each cubic yard of gravel where banks are, say, 30 ft. high, with about 85-ft. head of water.

TABLE I.—Cost of Mining Five Claims of the La Grange Hydraulic Mining Co. (1874-6, inclusive.)

	Claims				
	French Hill.	Light.	Cheanan.	Johnson.	Sicard.
Height of bank	10 to 40 ft.	24 to 60 ft.	12 to 62 ft.	20 to 40 ft.	20 to 40 ft.
Head of water	50 to 70 ft.	60 ft.	50 to 80 ft.	80 ft.	90 ft.
Nozzles	4. 5 and 6-in.	6 and 7-in.	6 and 7-in.	.....	.....
Grade of sluices	4 ins. in 16 ft.	4 ins. in 16 ft.	3 to 4". 16 ft.	3½" in 16 ft.	3½" in 16 ft.
Total cu. yds of gravel	679,968	683,244	284,932	196,632	155,347
Cu.yds. gravel per miners inch (2,159 cu.ft.)	1.08	1.52	1.87	1.76	2.89
Cu. ft. of water per cu. yd.	2,000	1,186	1,577	1,227	757
Labor per cu. yd. gravel	$0.0420	$0.0220	$0.0360	$0.0200	$0.0250
Blocks and lumber per cu. yd. gravel	.0042	.0080	.0042	.0029	.0061
Materials per cu. yd. gravel	.0057	.0015	.0062	.0076	.0038
Water per cu. yd. gravel	.1040	.0060	.0080	.0060	.0040
Refining gold per cu. yd. gravel	.0004	.0003	.0005	.0004	.0007
Total cost per cu. yd. gravel	$0.1563	$0.038	$0.055	$0.037	$0.039

The total yardage was 2,275,967 cu. yds. gravel moved by 1,533,728 miner's inches (2,159 cu. ft. each), or 1.48 cu. yds. moved per miner's inch, which is equivalent to about 1,440 cu. ft. of water per cu. yd. of gravel; 12,027 oz. of gold worth $231,893 were recovered, the average yield per cu. yd. of gravel being 10 1-5 cts.; 554 lbs. of quicksilver were lost. The average cost per cu. yd. of gravel moved was:

Water	$0.008
Labor	.036
Materials	.010
Office and general expenses	.06
Total	$0.06

As illustrating the expense to which certain companies have gone, the 55 miles of main ditch of the North Bloomfield Co. may be mentioned. This ditch was 5 ft. wide at bottom, 3½ ft. deep, and side slopes were 1½ to 1. The grade was 12 to 16 ft. per mile, and the delivery 3,200 miner's inches, or about 6,900,000 cu. ft. per 24 hrs. Ditches with grades of 20 ft. per mile and delivering 80 cu. ft. per second have been built, and it is to be noted that gagings show about 25% less discharge than open-channel formulas would indicate. Where ravines are crossed, timber flumes 4 ft. wide by 3 ft. deep laid on grades of 30 to 35 ft. per mile are used.

The sluices into which the loose gravel and water are run are made of 1½-in. plank, tongued and grooved, about 3 ft. wide × 3 ft. deep; cross-sills, 4 × 6 ins., support the sluice every 4 ft., being mounted on 4 × 6-in. posts. The sluices ordinarily have a 4% grade, and one of the size just given will carry 3,200 miner's inches on a 4% grade; 6 to 8% grades are used where pipe-clay is to be moved. The water must run at least 10 or 12 ins. deep in the sluice, so as to cover boulders of that size and facilitate their moving along. A sudden break or drop-off in the sluice line can be used to effect the disintegration of cemented gravels.

Banks of cemented gravel often weighing 3,600 lbs. per cu. yd., or 133 lbs. per cu. ft. in place, are broken up by using black powder. If the bank is 50 to 125 ft. high a tunnel is run in about two-thirds the height of the bank, and at the end of the tunnel lateral drifts are run parallel to the face, forming a T. One-half to ⅝ (25-lb.) keg of powder per 1,000 cu. ft. of gravel, measured in front and above the lateral drift, is the charge placed in the lateral drifts, tamped and fired. As illustrating the accuracy of sampling the yield of gravel determined by test pits and drifts, one example will suffice. Excavations from which 21,600 tons of gravel were taken actually yielded $2.75 per ton in gold, while the estimated yield by sampling was $2.00.

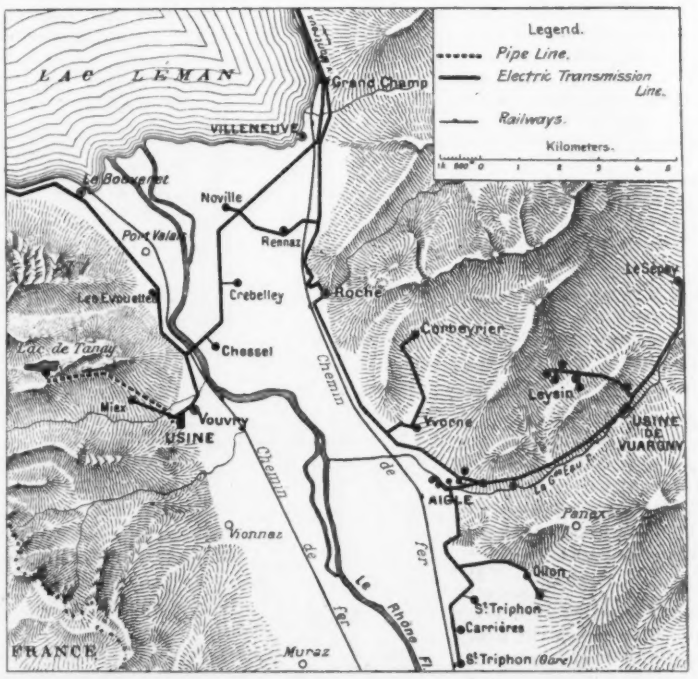


FIG. 1. MAP OF WATER POWER ELECTRIC PLANT AND TRANSMISSION LINES AT VAUVRY, SWITZERLAND.

Two shifts were worked and 1,520 (24-hr.) days were required to move the two and a-quarter million cubic yards, or about 1,500 cu. yds. per 24-hr. day per plant.

TABLE II.—Cost of Hydraulic Excavation; North Bloomfield Claim No. 8.

Year	1874-5.	1875-6.
Cu. yds. gravel	1,858,000	2,919,700
Height of bank, ft.	180	260
Grade of sluices	6½ ins. in 16 ft.	6½ ins. in 16 ft.
Labor per cu. yd.	$0.0122	$0.0140
Powder per cu. yd.	.0032	.0053
Materials per cu. yd.	.0030	.0031
General expenses pr cu.yd	.0022	.0025
Water per cu. yd.	.0077	.0074
Total per cu. yd.	.0203	.0323
Cu. yds. of gravel per miners inch	4.80	4.17
Cu.ft. water per yd. gravel	450	520

A WATER-POWER PLANT WITH A HEAD OF 3,116 FT. AT VAUVRY, SWITZERLAND.

A water-power plant whose wheels operate under the enormous head of 3,116 ft., is being constructed at Vauvry, Switzerland, on the left bank of the River Rhone, a short distance above the point where that stream empties into Lake Leman. The water whose power is used comes from Lake Tanay, having an elevation of 1,416 m. (4,644½ ft.), and the water wheels in the power plant have an elevation of 466m. (1,528.8 ft.), which makes the effective head of water 950 m. (3,116 ft.), and about 50% greater, we believe, than that of any other water-power plant in the world. The new plant is being built by the Société des Forces Motrices de la Grand Eau, to supplement its plant at Vuargny, on the opposite side of the valley, and to supply electricity for lighting and power purposes to a large number of Swiss towns and villages in the valley of the Rhone. Fig. 1 shows the locations of both the Vauvry and Vuargny plants, and of the transmission lines which they feed. These transmission lines now aggregate 127 km. (80.74 miles), and supply 63 stations, furnishing power for 20,000 10-c. p. lamps, and motors aggregating 450 HP.

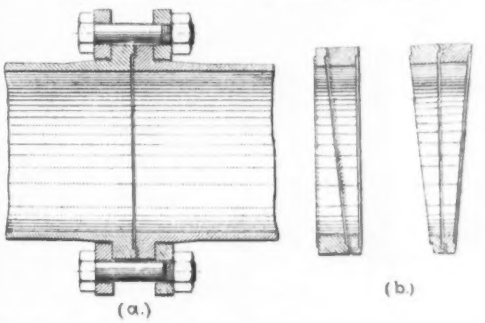


FIG. 2. DETAILS OF JOINT CONNECTIONS FOR PIPE LINE OF VAUVRY WATER POWER PLANT.

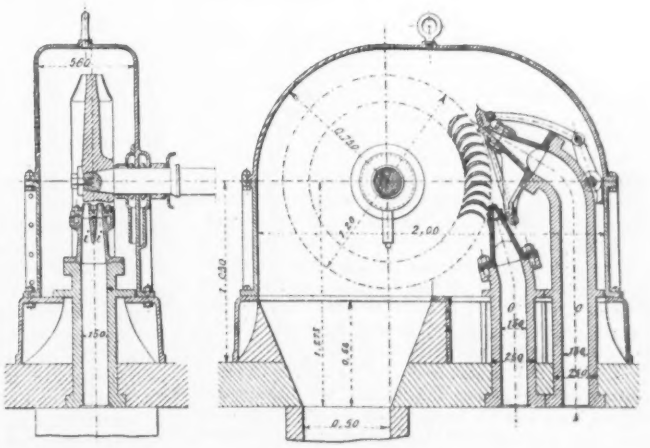


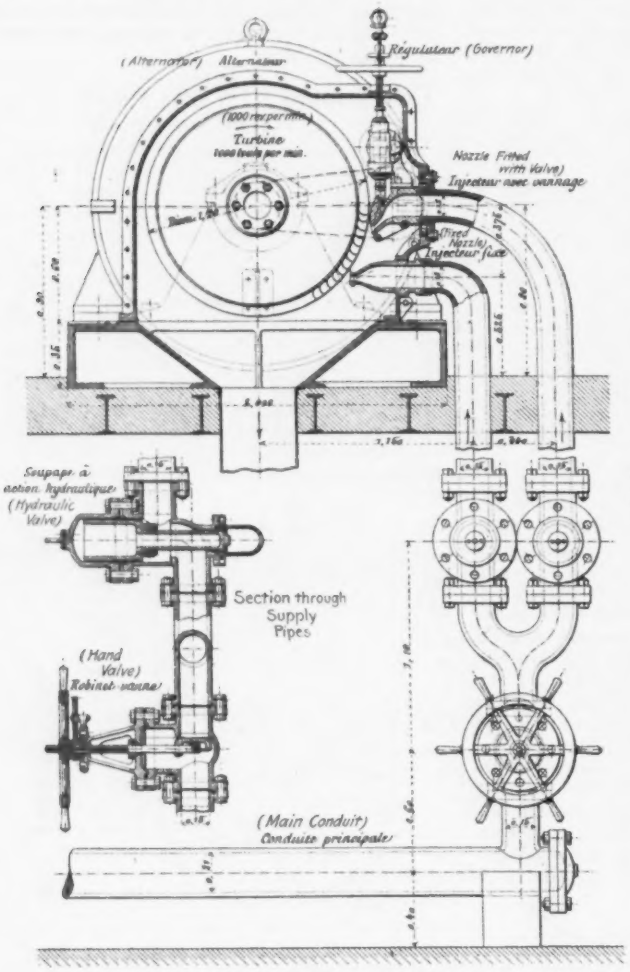
FIG. 3. DETAILS OF DUVILLARD WHEELS FOR VAUVRY WATER POWER PLANT.

The main structural features of the Vauvry water power comprise the supply pipe line and the power house and its machinery. Before describing these works, however, it is desirable to note that Lake Tanay, the source of the water supply has an area of about 45 hectares (112 acres) and receives the drainage of an area of about 750

hectares (1,875 acres), which, it is estimated, will supply annually about 11,000,000 cu. m. of water, or a steady stream of 346 liters per second.

SUPPLY PIPE LINE.—The head of the supply pipe line is at an elevation of about 1,390 m. (4,559 ft.), which is about 20 m. (65.6 ft.) below the normal level of the lake and 26 m. (84.2 ft.) below its maximum level, and it terminates in a vertical shaft about 30 m. (41.7 ft.) deep. From the shaft a gallery or tunnel 300 m. (984 ft.) long and with a sectional area of 3 sq. m., is built on a nearly flat grade. This tunnel is provided with bulkheads, pipes, valves and other apparatus for regulating and controlling the supply of water taken from the lake. At its end the pressure pipe line begins. For 100 m. (328 ft.) this line is a steel tube 0.8-m. (2.62 ft.) in diameter, then for 300 m. (984 ft.) it is masonry tunnel, and then for 1,206 m. (3,936 ft.) it is steel pipe 0.8-m. (2.62 ft.) in diameter. At the end of the 1,200-m. section the 0.8-m. pipe terminates in three pipes, each 0.5-m. (1.64 ft.) in diameter. One of these pipes extends to the power plant, but the others are plugged, and will be built to the power plant only when the demand for power necessitates their construction. At the point of junction of the single and triple pipe line the head of water is only 21 m. (689 ft.), but from this point on the descent is very abrupt. At this point also there is a retaining valve and a vertical pipe 0.4-m. (1.31 ft.) in diameter and 25 m. (82 ft.) high, open at the top, which relieves the water hammer in the pipe line above.

The steep grade pipe line from the junction point just mentioned to the power house is 1,940 m. (6,363 ft.) long, and has a fall of 900 m. (2,952 ft.). As stated, the pipe is 0.5-m. (1.64 ft.) in diameter at the junction point, and it continues at this diameter for 635 m. (2,682.8 ft.), varying in thickness of shell from 7 mm. to 11½ mm., and terminates in a Y, each branch of which has a valve. From the branches of the Y two 0.341-m. (1.12 ft.) pipes extend 1,306 m. (4,264 ft.), with shells varying in thickness from 8 mm. to 18 mm. The material of the pipes is open-hearth steel welded into cylinders. The transverse joints are made as shown by Fig. 2a. To make these joints tight a ring of leaded copper enveloping a cord of asbestos is inserted before the bolts are tightened. As the pipe lies in a trench following the surface grades, it has many bends, and to provide for these the wedge-shaped annular pieces shown by Fig. 2b are inserted at the joints. The sections of pipe used varied in length from 5 m. (16.4 ft.) to 10 m. (32.8 ft.), and weighed from 800 to 1,000 kgms. They were conveyed to the work and handled into position by a cableway. Each branch of the pipe line has at its lower end a slide valve provided with a by-pass to permit it to be operated by hand.



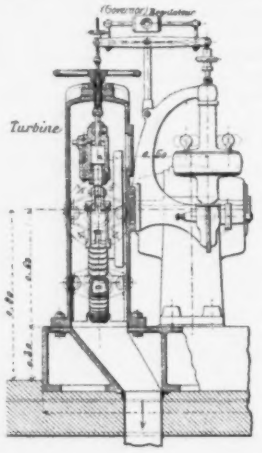


FIG. 4. DETAILS OF WHEELS SUPPLIED BY THE SOCIETE DE CONSTRUCTIONES MECANIQUES DE VEVEY FOR VAUVRY WATER POWER PLANT.

POWER HOUSE MACHINERY.—The power house is a steel building, 14 × 66 m. (45.9 × 216.5 ft.) in plan. The two pipe lines described terminate underneath its main floor, and each supplies water to two turbines, one pair of which was constructed by Mr. Duvillard and the other by the Société de Constructiones Mecaniques de Vevey. All of the wheels are of the impulse type.

A transverse and longitudinal section through one of the Duvillard wheels are shown by Fig. 3, and a plan, elevation and sections of one of the Société de Constructiones Mecaniques wheels are shown by Fig. 4. As will be seen, each wheel is supplied with water by two nozzles, one above the other, the uppermost of which is provided with a device for cutting-off the water, which is operated by a governor. A vertical diaphragm divides the end of each nozzle into two openings, as shown by Fig. 3. The pipe by which the nozzles are supplied rises vertically from the main and is opened and closed by a hand valve. Above this valve it bifurcates into two pipes, one leading to each nozzle and each opened and closed by a hydraulic valve operated from the operator's platform on the floor above. Each wheel is mounted on the shaft of an alternator, and they operate at 1,000 r. p. m. The dynamos are each 500 HP. The other features of the construction are clearly shown by the drawings.

We are indebted to "Le Genie Civil" for the information from which this description has been prepared.

LOCOMOTIVE COALING STATION OF THE WISCONSIN CENTRAL RY. AT FOND DU LAC, WISCONSIN.

The Wisconsin Central Ry. has recently established at Fond du Lac, Wis., a coal storage and coal handling plant for supplying the locomotives, the coal being stored in large uncovered piles on the ground. There are four coal piles with a capacity of about 3,250 tons each, or 13,000 tons in all. The coal handling plant consists of a receiving pit under the coal car track, with a conveyor to supply two 75-ton coaling pockets and to deliver the coal to four cross conveyors at right angles to the main conveyor, and extending over the four coal piles. The coal on the ground may be delivered to the return side of the cross conveyors and main conveyor to be elevated to the pockets. The number of coal piles can be increased as required by extending the main conveyor and building additional cross conveyors. The general arrangement is shown in Fig. 1.

The coaling tower and trestles are of timber construction, as shown in the drawing, Fig. 2. The pockets are of 3-in. plank, lined with No. 16 sheet steel, and have a pitch towards the inner corner on the track side, where the gate and the hinged tender chute are attached. This chute is 13 ft. 6 ins. clear above the rails. The tower is 35 ft. long and 20 ft. wide, with a height of about 65 ft. The main conveyor descends on an incline from the top of the tower to a trestle 40 ft. high. The total length from the rear of the tower is about 110 ft., and at the end of the trestle is a smaller tower through which the conveyor descends. The four lateral conveyors run on trestles 35 ft. high, their ends extending under the main conveyor. These trestles are 160 ft. long, with 16-ft. bents. All the conveyors return in concrete-lined pits below the ground. Those of the cross conveyors are covered with planks, which may be removed to let the coal fall in upon the conveyor, which delivers the coal at the end where these pits cross that of the main conveyor.

When coal is received the cars are run on the track which passes under the pockets, and their contents are dumped or shoveled into the receiving pit or hopper beneath the track level. Under this pit passes the main conveyor, at right angles to the track, and this carries the coal up to the top of the tower. If the coal pockets are to be filled a gate is opened and the buckets discharge the coal upon a hinged flap gate, which diverts it laterally to a chute leading into one or the other of the two pockets, as required. If the coal is to be stored, the conveyor buckets continue down the incline and along the trestle, where the coal is discharged through a

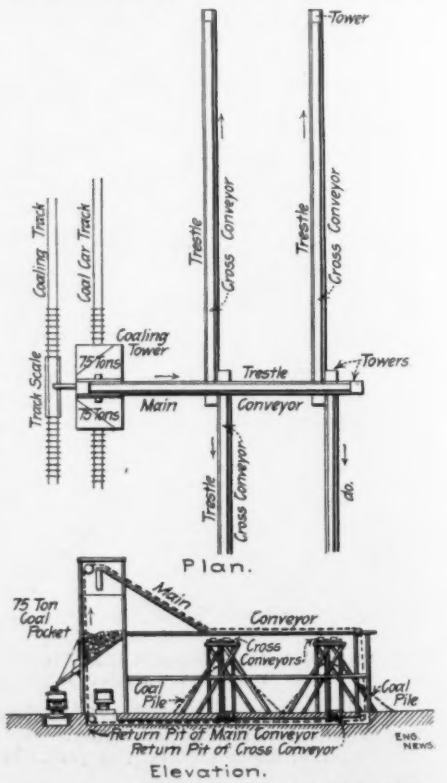


Fig. 1. General Arrangement of Coaling Station at Fond du Lac, Wis.; Wisconsin Central Ry. W. C. Menzel, Superintendent of Motive Power and Cars; Fairbanks, Morse & Co., Chicago, Builders.

gate into one of the cross conveyors, which in turn dumps it upon the stock pile at any required point. If it is desired to replenish the pockets from the stock piles, some of the planks covering the return pit of one of the cross conveyors are removed to allow the coal to fall into the conveyor. Where this crosses the return pit of the main conveyor the coal is discharged at the end into the latter, by which it is conveyed to the tower and elevated as before.

At the top of the tower all the coal passes over a screen before reaching the discharge gate for the pockets, and through this screen the dust and dirt falls into a bin or pocket of 30 tons capacity. These screenings are used for fuel in the power house at the adjacent shops.

The main conveyor consists of steel buckets 30 × 22 ins. and 11 ins. deep, 32 ins. c. to c., attached to a double strand of steel roller chain. The cross conveyors consist of double chains, to which are attached steel flights or scrapers 30 × 20 ins., mounted on self-oiling wheels at intervals of 32 ins. The conveyor troughs are lined with ¼-in. steel plate, and have horizontal sliding gates of ¼-in. steel operated by a rack gearing with a pinion on a vertical hand-wheel shaft. The five conveyors are all driven by a 50 HP. electric motor. The main pulley drives a shaft connected by a sprocket chain with the shaft of a bevel gear at the top of the tower operating the main conveyor. A shaft running along the trestle of the main conveyor may be driven from the main shaft by a friction clutch coupling, and has sprockets with chains for driving the four cross conveyors by pinions and spur gears. Jaw clutches enable any one of these chains to be thrown into gear. The main conveyor has a speed of 87 ft. per minute and a capacity of 96 tons per hour. The cross conveyors have the same speed as the main conveyor.

A 100-ton Fairbanks track scale under the chute from the pockets enables the exact amount

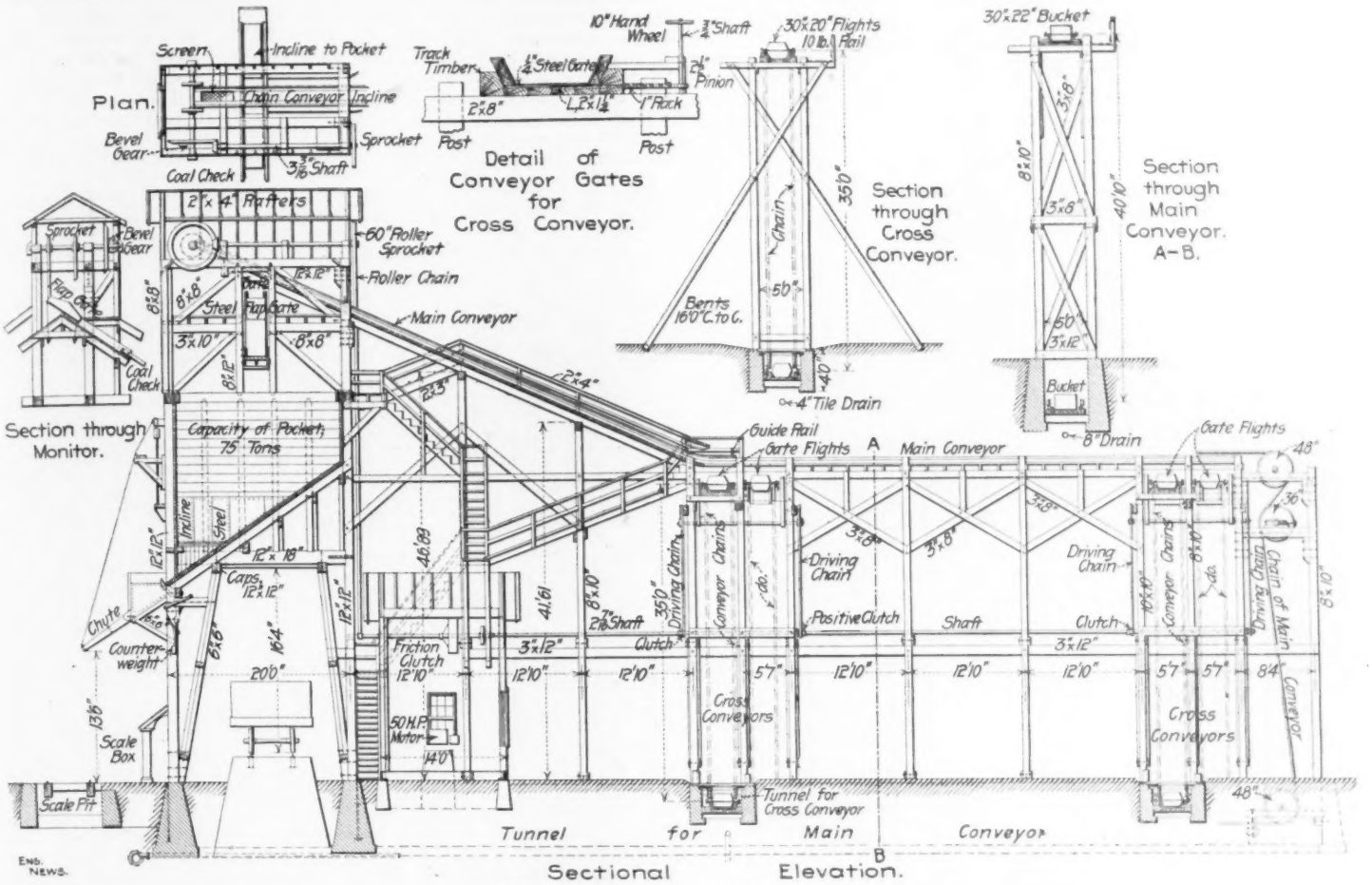


FIG. 2. DETAILS OF COALING STATION.

FIG. 3. VIEW OF COALING STATION FROM ABOVE.

of coal taken by each engine to be ascertained. The entire plant was erected by Fairbanks, Morse & Co., of Chicago, and we are indebted to them for plans and other information.

Fig. 3 is a side view showing the tower with pockets and chute, the inclined portion of the main conveyor and the end of the horizontal portion of this conveyor. Parallel with the railway tracks run the cross conveyors; the tower at the end of one of these (through which the chain descends to the return channel) appears in the middle of the view. Fig. 4 is a view from near the end of one of the cross conveyors, showing the top of the tower and the inclined and horizontal portions of the main conveyor.

This new coaling station has been established in connection with the new shops and other facilities at Fond du Lac. About two years ago the Wisconsin Central Ry. decided to effect an economy in the maintenance expense of its equipment by concentrating all its heavy repair work at one large shop plant, leaving only minor and running repairs to be made at other points. The place selected for the new shops was Fond du Lac, and some of the older shops at other places have now been abandoned. The main line extends from Chicago and Milwaukee to St. Paul and Minneapolis, 475 miles, with a branch of 152 miles from Abbotsford to Ashland, Wis.; other branches bring the total length of the system up to 937 miles. The equipment includes 161 locomotives and 8,220 cars. All this equipment is now taken care of at the Fond du Lac shops. The plant consists of two main buildings; one of these, 527 ft. long and 128 ft. 8 ins. wide, containing the locomotive repair and machine shop, blacksmith shop and boiler shop. The other building contains the car repair shop, woodworking shop and paint

shop. These buildings are parallel, 110 ft. apart, and are served by a 70-ft. transfer table running between them.

The fact of the shops being located at this point of course increases the number of locomotives to be provided with coal and water, and at the present time about 20 engines per day now take coal at Fond du Lac. The average amount is 9 tons per engine.

CONSTRUCTION WORK ON THE SOUTHERN PACIFIC CUT-OFF ACROSS THE GREAT SALT LAKE, UTAH.

By C. W. Arthur,* C. E.

The Southern Pacific cut-off across the Great Salt Lake from Ogden to Lucin will be one of the marvels of present day railroad construction. The work on this cut-off is attracting the attention of not only the railroad engineers of the West, but of foreign countries as well.

The Ogden-Lucin cut-off† when finished will be 104.5 miles in length and will save a distance of 45 miles over the present route, to say nothing about reducing the curves and grades of 21 ft. to the mile, and to all intents and purposes will be an air line.

The present line from Ogden to Lucin is 145.5 miles long, and leads around the north side of the lake, running some 50 miles north and northwest before turning westerly. More objectionable even than the increase of distance due to the long detour or the many curves are the heavy grades required in getting over Promontory and Kilton Hills. The elevation of the former summit is 4,905 ft., and of the latter 4,701, though other parts of the line, but a few miles distant, are a little above the surface of the lake, which is 4,200 ft. A shore line along the north side of the lake is out of the question, on account of the extreme irregularity and length of the same.

The projected line as being built runs west from Ogden to the shores of the lake, crossing to Promontory Point on an embankment and trestle. This point is crossed by 5.3 miles of heavy cut and thence the line runs across the main body of the lake to Strong's Knob on the west shore and thence to Lucin over an easy grade. The total length of the new line will be 102.5 miles, a saving in distance of 44.8 miles. The new line will have a maximum grade of 21 ft. to the mile. The line from Promontory to Strong's Knob will be level and nearly on a tangent. The fall from Ogden to the east shore of the lake is 100 ft., and the rise from Strong's Knob to Lucin is 100 ft. in 52 miles.

Work has been going on all summer, with the result that the land section from Ogden to the east shore of the lake is practically completed except two steel bridges, around which temporary tracks have been laid. On this portion of this line, exclusive of the bridges mentioned, there are no less than 44 openings, which are bridged with solid masonry culverts or steel pipes, over which the grade is built. The excavations for these openings are about 100 ft. long and average 12 ft. in width and 13 ft. deep. In the bottom piles were driven and sawed off 12 ins. above the bottom of the excavation and concrete placed around and on top in courses 8 ins. thick, and the whole tamped to a water face.

From the lake shore to the Promontory is a distance of 8.4 miles. Of this distance the work of building out 2.8 miles was attended with great difficulty, as the water had greatly receded, leaving a bed of mud, which was in many places from 8 to 10 ft. thick under the salt crust.

In order to lay a construction track under these difficulties, planks were first laid and upon them were placed sand bags of about 100 lbs. each, three layers deep; upon these 12 × 12-in. × 10-ft. cross timbers were laid, and then came three stringers, 8 × 16 ins. × 30 ft., upon which ties are placed and temporary track laid. The center of this track is about 8 ft. south of the track center stakes of the permanent track. This mode of construction was carried on for some three miles, a portion of the way through soft salt crust and mud, the remainder through water from one to two feet deep, under which the soft formation continued. Upon this track cars loaded with shale and gravel are run out, dumping their load to the north side to form the permanent grade.

It is near the end of this work that the big boat which has been christened "The Promontory" is nearing completion. This specially constructed stern wheeler will in all probabilities be placed in commission within the next 30 days. It is 127 ft. long, with a 22-foot beam, and draws but 18 ins. of water, and will be run by two 500-HP. engines. When complete she will carry two fresh water tanks with a capacity of 15,000 gallons each. The upper decks will have a well-fitted cabin for the accommodation of officers and guests of the road who may have occasion to visit the work. She will also carry food and water and other supplies to the temporary stations on the lake.

The water problem has been a serious one in the work of construction. Most of the supply has been hauled from Ogden. To obviate this, the company put down an artesian well in the lake about four miles from the east shore, and another about two miles inland. The former is now discharging a good flow of water, from which pipes are being laid to carry water to the different stations. The latter well was sunk to a depth of 340 ft., and at first gave a good flow of fresh water, but is now abandoned, as the present discharge is about one-eighth sand and wholly unfit for use.

When water of a depth of from four to five deep was reached in the lake the manner of construction was entirely changed. Pile driving operations were started at four places at intervals of about one mile apart, eight floating pile drivers being used. Each bent has four 40-ft. piles, capped with a 12 × 12-in. timber, and the bents are spaced 15 ft. apart. Upon the caps are placed 8 × 16-in. × 30 ft. stringers, on which the ties and rails are laid.

Great differences have been encountered in the nature of the bottom of the lake while driving the piles. At times a blow of the hammer did not drive the pile more than one or two inches, and at other times a blow would drive it as many feet. Again many blows did not seem to have any effect whatever, the bottom of the pile having struck a hard strata. After passing through this, the pile would sink as much as two or three feet at one blow. Frequently a pile after having been driven from 30 to 50 ft. would rise from a few inches to two or three feet during the short delay of the hammer.

Eventually this temporary trestle will be rock filled, leaving the bents in place, thus filling up the bed of the lake around the trestle, which will be an additional factor in strengthening the line. The work of filling can be done at the company's leisure.

Just before reaching the site of the permanent trestle, at the end of the work mentioned above, a serious difficulty was encountered. The first pile, 26 ft. long, was driven out of sight by one blow of the hammer. The second, 28 ft. long, was set upon the first, and a second blow sent both out of sight. The formation at this point is of mud deposited by the Bear River, which flows into the lake from the north. Upon examination it was found that mud to the depth of 50 ft. had accumulated. To cope with this "out-of-sight" pile driving, two 40-ft. piles were driven, tied, capped and braced, and when the rails are laid it is thought they will be strong enough to hold the construction trains while dumping their loads of fill, and in time the whole structure will become solid.

When deep water was reached where the swift current of the Bear River forms a channel, 600 ft. of permanent trestle will be built, and will be the only open trestle on that section of the line from the east shore to the Promontory. A hard-pan bottom here affords excellent support for the piling.

In the latter part of July work was started on the Promontory section. This contract calls for a little more than 4.5 miles of work, most of it being in the nature of a very heavy cut. This will take some four months to complete, and was the last contract to be let on the work.

The formation of the lake's bottom on the western section from Promontory Point to Strong's Knob, a distance of a little over 20 miles, is entirely different from that encountered on the eastern section. The salt crust is not so pronounced, but according to local experts it is thought that much difficulty will be found in certain portions of this line in driving piles. It is claimed by many that under this thick salt crust will be found a very hard strata which will give much trouble.

The top of the trestle on this section will be 15 ft. above the level of the lake, and will be solidly

FIG. 1. EASTERN SECTION OF EMBANKMENT ACROSS GREAT SALT LAKE; SOUTHERN PACIFIC RY.
Sandbags Laid for Temporary Construction Track Still In Place.

FIG. 2. PART OF THE TEMPORARY TRESTLE, TO BE FILLED IN; VIEW LOOKING TOWARD PROMONTORY POINT.

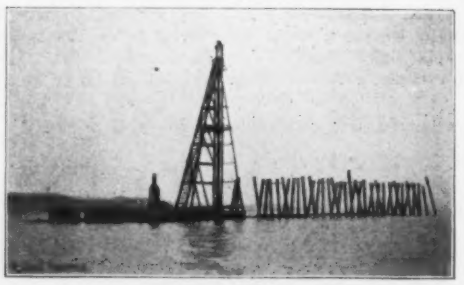


Fig. 3. Pile-Driving for 600-ft. Permanent Trestle.

*See Eng. News, Feb. 22, 1902, p. 175.
†Box 1386, Seattle, Wash.

built, using 70-ft. piles heavily braced. After the trestle is in position train loads of material will be dumped in the center in the same manner as described above. On this portion there will be about 12 miles of permanent open trestle, at just what point on the line as yet has not been made public.

Grading is now being rushed west from Lucin to Strong's Knob, with the tracklayers closely following, with the result that a material yard will soon be established on the west shore of the lake, and work from this point will commence across the lake toward the Promontory.

There are several things about the work that are not quite as the contractors anticipated. It was intended that the men working in the water of the lake should wear rubber boots. Owing to the action of the salt water on the boots it was abandoned, as the footwear soon became useless. The result is that the men go into the water at all hours during the course of the work in ordinary attire. Those who have scratches or sores on their persons have found that building a railroad across the lake is not such easy work. But with all this, nothing will prevent the engineers and contractors from reaching their destination, and it is safe to say that January, 1904, will see trains running over the great cut-off.

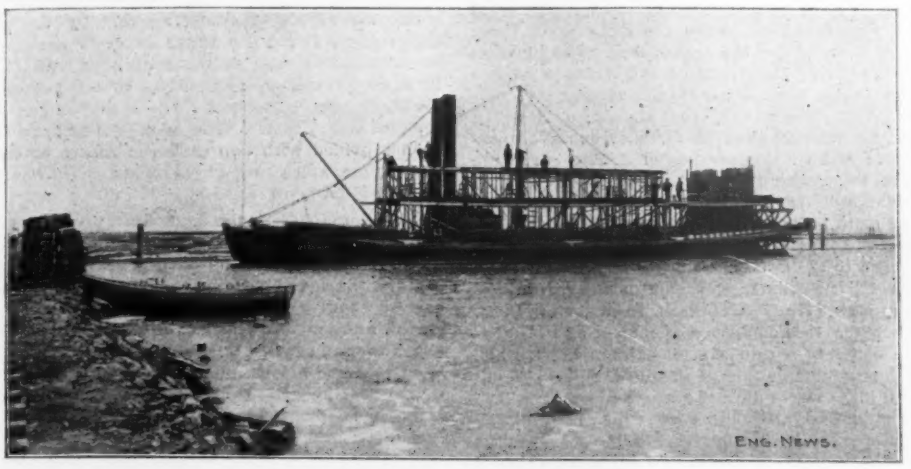


FIG. 4. THE SHALLOW-DRAFT STEAMER "PROMONTORY" UNDER CONSTRUCTION.

STATIC AND DYNAMIC LOAD TESTS OF DE VALLIERE FIREPROOF FLOOR CONSTRUCTION.

By E. S. Powers.*

On Sept. 30, 1902, a test was conducted under the direction of Mr. Robert C. Hill, Chief of the Bureau of Building Inspection of the city of Philadelphia, Pa., of a reinforced concrete fireproof floor construction, "System De Valliere," as executed by Mr. J. O. Ellinger. Mr. Ellinger's methods follow closely those of the European constructors, with whom he studied for several years. Of the two floor constructions tested, one was tested statically and the other dynamically. It was originally intended to have only a statical test as a visual demonstration of the strength of the floor; but later it was decided to have a dynamical, or drop test. It was from this test that the most interesting results were obtained, the floor slab being tested to destruction. Unfortunately, however, preparation had not been made for accurate or scientific observations of the test.

Before stating the results of the tests it will be well to explain briefly Mr. Ellinger's methods. He constructs walls, columns, floors, ceilings, roofs, stairs and even newel posts of cement concrete. The concrete used in most of this work is one part cement, three parts sand and five parts stone. The stones range from 1 to 1¼ ins. across. The floor is reinforced by steel rods of varying diameters in a direction at right angles to the beams or supporting walls. These rods are without twists or indentures of any kind to increase the adhesion. They are of steel, with an ultimate tensile strength of about 62,000 lbs. per sq. in. The rods are placed 1 in. from the bottom of the slab.

STATIC LOAD TESTS.—The beams tested were reinforced with four 1-in. diameter rods of the same grade of steel as the rods in floors. Fig. 1 is a scale detail of beams. The test slabs were fair examples of the floors and beams found in the buildings executed by Mr. Ellinger, except for one thing, viz.: in such buildings there are generally several points of support for the floor slabs, and the rods imbedded therein, as noted above, run continuously across several beams, whereas in the test slabs the rods at right angles to beams were very short, being only 4 ft. 4 ins. long, as shown by Fig. 2, which is a scale detail of one of the test slabs, and in consequence had a much less area for adhesion than the rods in the floors of buildings generally. To compensate for this lack of continuity, Mr. Ellinger placed in the slab used for the dynamic test, another series of rods 6 ins. apart, at right angles to the first, or parallel with the beams, forming a 6-in. mesh.

The slab united with the beams to form a resisting section. In the case of the test slabs, it will be seen by reference to Fig. 2, that the resisting section is that of a channel with the flanges turned down. And this is the way Mr. Ellinger calculates his floors and beams, viz.: as acting together as a whole.

The concrete in the test slabs was six weeks old when tested. The underside of beams had a slight initial deflection, due to the deflection of the centering. One of the slabs was loaded with 10,000 lbs., and the instrument set for registering the deflection, indicated 0.04-in., then the load was taken off and the instrument went back to zero. Then about 26,000 lbs. was placed on the slab and the gage registered 0.125-in. deflection.

While placing on more load, and when the gage was registering 0.14-in., the gage was accidentally displaced; but very nearly all of the load available was on, viz., 32,000 lbs. of pig igon. This load was left on the slab for three days and then, on Oct. 3, was removed and the deflection entirely disappeared. The load, as will be seen by referring to Fig. 2, was uniformly distributed over an area of, 4⅓ ft. × 3 ft. = 13 sq. ft.; 32,000 ÷ 13 = 2,461 lbs. per sq. ft.

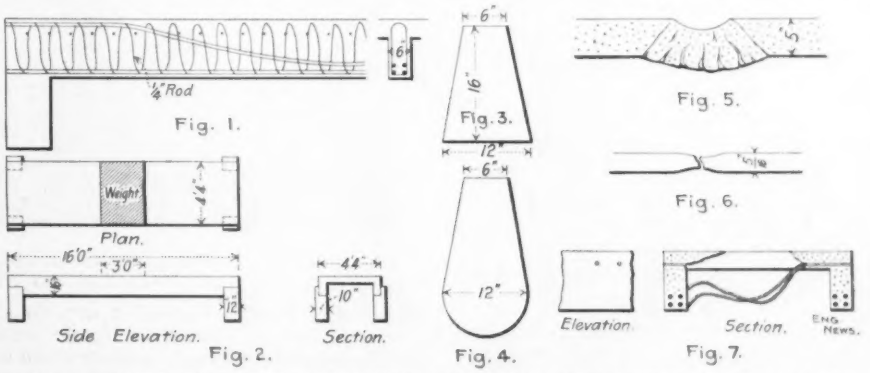
DYNAMIC LOAD TESTS.—The weights used were cast iron, shaped as shown in Figs. 3 and 4, weighing 250 and 600 lbs., respectively. These weights were dropped on the center of the slab from a height of 12 ft. The slab used for these tests was the same as shown in Fig. 2. The 250-lb. weight was dropped first, striking somewhat on one edge, and only caused a displacement of some of the stones in the top of the concrete slab and in nowise injured it. Then the 600-lb. weight was dropped five times from the same height. Before the first drop was made there was placed on the slab where the weight would strike some sand about 2 ins. deep. This was done to distribute the force of the blow. The first drop caused an indenture in the top of slab, but unfortunately the depth of this indenture was not measured, so the force of the blow cannot be correctly calculated; but, say it was 2 ins. deep, then the force of blow would be 12 × 600 ÷ 1-6 = 12 × 600 × 6 = 43,200 lbs., applied practically on 4 sq. ins., taking into account the distributing effect of sand.

The general effect caused by the 600 lbs. being dropped is shown in Fig. 5. The edge of the indenture on the top of the slab was a clean circle without any radiating cracks, nor were there any radiating cracks on the bottom of the slab, the concrete simply bulging out in a larger circle and the only cracks were inside of the circle. The diameter of the indenture was not observed exactly; but was about as shown in Fig. 5.

Each successive drop enlarged the indenture until the weight broke through the slab. No cracks developed at any time throughout the entire test except directly under the weight and inside the aforesaid indenture. After the third drop the concrete inside the indenture was broken up sufficiently to see daylight through the cracks in one place. After the fourth drop the broken pieces of concrete were all cleaned out, leaving the naked rods, which, as noted before, were 5-16-in. in diameter, and in this case formed 6-in. meshes.

The fifth drop broke one of the rods running the 16-ft. way of the slab as though it had been broken in a testing machine, see Fig. 6. As is shown there, the rod was not sheared off, but stretched beyond its elastic limit until failure took place, showing that the adhesion of the concrete to a 5-16-in. rod exceeds the tensile strength of the rod when about 6 lin. ft. of the rod is imbedded in the concrete. Two of the cross rods slipped through the concrete, pulling out, as is shown in Fig. 7. These rods were first forced, or torn down through the bottom of slab up to the point where the slab joined the beam; here the shearing strength of the concrete in beam exceeded the adhesive strength of concrete to rods, also, the tensile strength of rods exceeded the adhesive strength, so they pulled out. The ends of these rods were imbedded in concrete 6 ins. (the thickness of beams) where they pulled out. The rods were 5-16-in. in diameter, therefore their adhesive surface = .9817-in. × 6 ins. = 5.8902 sq. ins. per rod.

These tests were interesting, but not as instruc-



FIGS. 1 TO 7. SKETCHES SHOWING METHODS AND RESULTS OF TESTS OF DE VALLIERE CONCRETE-STEEL FIREPROOF FLOOR CONSTRUCTION.

*West Collingwood, N. J.

tive as they would have been had more thought been given beforehand, as to what to observe and how to observe it. Nevertheless they accomplished the purpose of showing that this form of construction far exceeds the requirements of any building.

Mr. Ellinger is an engineer of considerable practical experience both in this country and in Europe, besides having a thorough theoretical training, and he is anxious to assist the engineering profession in acquiring reliable data that can be used in developing the art of reinforced concrete construction. With this aim in view, he is arranging for a series of tests at which he hopes to have some men prominent in the profession present.

A 128-FT. WOODEN SWING BRIDGE OVER BARNEGAT BAY, MANTOLOKING, OCEAN COUNTY, N. J.

By Franklin Van Winkle, M. E.*

While in average engineering practice of the present day general interest in the designing of wooden bridges is mainly confined to roughly-framed structures for temporary purposes, the practice of building wooden highway bridges of more elaborate design and intended for greater permanency still obtains in many country districts where structures of this class meet the requirements of cost and other local conditions. The wisdom of employing a material less durable than steel because it results in less first cost will, of course, depend on circumstances. Economic arguments, analogous to those which often prevail against employment of expensive structures of masonry in railroad work, exert powerful influence in country districts in favor of wooden highway bridges. In cases where eventual requirements are conjectural, as, for instance, the propriety of making provision for passage of trolley cars or other increase of traffic, the employment of a more temporary and less expensive bridge structure would seem warrantable.

It is, therefore, quite probable that for good practical reasons, as well as conservative financial considerations, wooden-framed bridges, possessing greater or less merit of design, will be constructed in many rural districts for years to come, and although there is now less occasion for that universal interest which different types of this class of construction commanded comparatively a few years ago, when wooden-framed bridge structures were the only ones generally available, the demand for structures of this kind is by no means extinct. Wherever required, however, they are as much as ever worthy of good engineering treatment. In this connection it is worthy of note that the natural growth and development of many country districts are held in check for want of bridge facilities proportionate to those possessed in the earlier history of their settlement. Less favored sections continue to bear the burden of maintaining expensive improvements at primitive bridge sites and remain deprived of needed bridge facilities for lack of public funds for "imperishable" structures and a fair understanding and acknowledgment of engineering possibilities procurable in the way of less expensive improvements.

One reason, undoubtedly, for less consideration being given to wooden bridges than formerly is the absence of professional framers of wood. Most of the early bridges were designed and built by that sturdy class of old-time carpenters known as master framers, a branch of trade now almost obsolete because their main occupation, which was framing of wooden buildings, has given way to a cheaper and simpler form of framing buildings known as "balloon framing," made practicable of late years by the low price of spikes and nails. Present-day carpenters are, however, better equipped with tools, appliances and materials for bridge building than were the old-time framers, and what the modern woodworker may lack of experience in arranging and proportioning parts of wooden bridges can be more than compensated by intelligent engineering guidance in production of bridge structures of better design, material and workmanship, and relatively cheaper and much better adapted to present-day requirements.

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One of the most important of recent contributions to structures of this kind is a 128-ft. draw span, with a 16-ft. roadway, forming part of the county bridge over Barnegat Bay at Mantoloking, Ocean county, N. J., and which has been in very satisfactory operation since its completion in March last. The structure was designed by the writer, who also prepared the plans and specifications providing mainly for material and labor common to the locality of the bridge.

As the working conditions of a draw span are much more complex than with fixed spans, the readers of Engineering News will be interested, perhaps, in following a brief description of this structure, the design of which presents a number of features which are novel in construction of wooden draw spans. A very good idea of the general appearance of the span may be obtained from Fig. 1, which shows the draw span open, viewed from one of the approaches. The illustration, however, being reproduced from a photograph taken with a panorama camera at comparatively close range, due allowance is to be made for exaggeration in foreshortening of perspective and the appearance of double curvature of the lower chords, which are in fact parallel, straight and level.

The main bridge is supported on pile bents 15 ft. apart and has a roadway 16 ft. wide, the approaches to the draw span being inclined upwards to meet 2 ft. greater elevation of the latter.

The draw pier is circular in form, being 16 ft. in diameter. It is composed of cement and broken-stone concrete within a steel caisson 11 ft. high, and has a foundation of 32 piles, spaced about 2 ft. 6 ins. centers over the whole area. The bottom of the bay consisting of a 12 to 16-in. top layer of fine sand underlaid with coarse sand and shells to great depth, the piles were jetted down 12 ft., with their heads set or cut off below low-water mark, i. e., about 5 ft. above bottom. Jetting was also employed for clearing off and leveling the bottom between the piles and for settling the caisson to good bottom. The main purpose of the caisson being that of a box form for the concrete and protection for the concrete during several years of hardening, the shell of the caisson was made of ¼-in. steel, bolted together in sections, and provided with an angle-iron stiffening ring around the top for preservation of good circular form. In construction of the pier the caisson was readily jetted down to proper level, after which the concrete was filled in between and over the heads of the piles and built up to the top of the caisson. Anchor bolts for the machinery were supported by templates and embedded in the concrete in the usual manner.

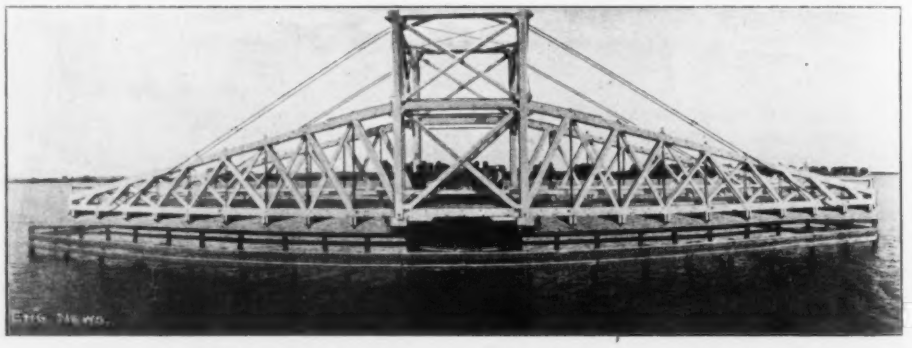


FIG. 1. WOODEN SWING BRIDGE OVER BARNEGAT BAY, OCEAN COUNTY, N. J.
Franklin Van Winkle, New York City, Engineer.

The draw span is of center-bearing type, the whole of the dead load being carried on a Sellers conical roller-bearing center, the cast-iron base of which is circular, and has a spread on the pier 4 ft. in diameter. The trailing wheels shown on the plan of turntable, Fig. 2, are employed only for supporting any unbalanced load and to resist the overturning action of the wind.

The construction of the turntable will be best understood by reference to the plan, Fig. 2, from which it may be observed that all parts are so arranged as to readily permit of inspection, adjustment, repair or renewal. A platform framed of 12 × 16-in. yellow-pine timbers laid and hung in pairs is supported by two pairs of steel beams, each pair being suspended from the ends of a curved cast-steel yoke resting on the center at the middle of its length, and bringing the point of suspension close up under the planking of the roadway, well above the center of gravity of the turntable.

The superstructure above the turntable may be said to consist of a central tower framing with adjustable tension members supporting two independently trussed arms. This is, however, strictly true only of the normal working conditions, when the lower chords are built continuous from end to end of the draw span, while the upper chords of the arm trusses are extended from the ends of the lower chords to points which are about half way up the length of the tower posts and are connected across the center panel by tie-rods. These upper chord ties afford auxiliary cantilever effect sufficient for safely supporting the arms in event of temporary deprival of support from the main suspending rods, due to accident or for repairs to the latter. The ends of the arms are each provided with two cast-iron rollers or casters, whose axles are set in boxes with vertical screw adjustment.

The approaches to the draw span are each provided with level sills of the same height for receiving either end of the draw span riding on its casters, the ends of the sills extending beyond the casters about 2 ft. on each end when the draw is closed, and cut down in height to form gentle inclines for the casters to run up to bearings on the level portions of the sills. The main adjustment of the bearing or end-lifting effect of the casters being accomplished by the screw adjustments of the latter, any degree of bearing from the fullest load to clearance of the casters is readily attained by means of the turnbuckles in the main suspending rods. The upper chord tie-rods are provided only with screw nuts for adjustment of their tension. They cannot, therefore, be brought to more than a mere bearing, nor be made to interfere with the broadest degree of vertical adjustment obtainable by the turnbuckles in the main suspending rods, which adjustment is, however, more than necessary for regulating the desired amount of bearing of the ends of the draw span when closed, an adjustment occasionally required in compensation for variations in dimensions of material of the structure, due to change of temperature and humidity. Inequality of balancing of the end spans is taken up by the bracing of the center panels. The greatest vertical adjustment ever thus required of the ends of the arms is not accompanied by a perceptible amount of bending of the lower chords at the turntable, and the very small amount of motion of approach or departure of the upper chords at the tower posts is taken up by the elasticity of the tie-rod connections.

The tower posts are supported at the corners of the turntable, and consists each of two pieces of yellow pine, 6 × 12 ins., with the chords passing between them. The main bracing of the center panels and tower framing are all of yellow pine. The saddle blocks and bolt blocks employed in tying together the tower framing are made of oak, and all other tie-bolt connections are made of cast iron. The whole of the framing is ar-

ranged in such manner that parts exposed to the weather may be readily examined, painted, repaired or renewed.

The chords throughout are built up of three sections of yellow pine, each 12 ins. deep, the outer sections being 5 ins. wide and middle sections 4 ins. wide. The sections are spaced 1¾ ins. apart by wood separators 3 ins. wide and 2 ft. apart, and held together by two ⅞-in. through bolts at each separator, thus forming of each chord a hollow-built beam 17½ ins. wide. The sections of chord timbers break joints square across their length, and are so arranged that no more than one cross joint falls to a truss panel, and in such manner as to bring the joints near the centers of panels wherever the chords are subject to end-grain shearing strains from the thrust of the braces.

The trussing of the overhung ends of the draw span may be described as types of multiple king-bolt trussing, divided up in lengths by pairs of equally spaced tie-bolts similar to trusses often employed for roofs, but capable of acting as cantilevers. The braces of these end trusses are made of clear cedar, a wood which is plentiful in the locality of the bridge, and is about as heavy as soft white pine, though rather harder, tougher and more durable. This material was milled in the locality, though it is not obtainable in dimensions of scantling and length economically adapted to the construction of the chords or where heavier timbers are required.

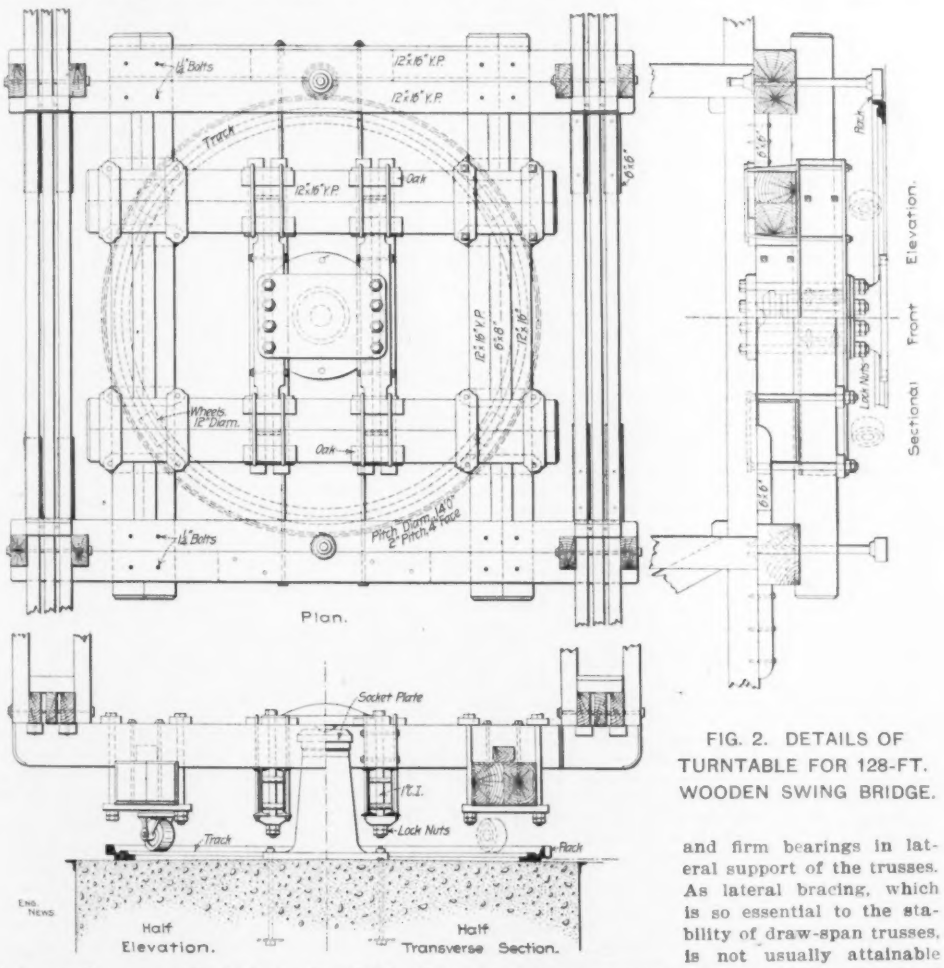


FIG. 2. DETAILS OF TURNTABLE FOR 128-FT. WOODEN SWING BRIDGE.

Considering each end truss as an independent span supported at its ends, the main braces, arranged in pairs, take bearings on the outer sections of the chords, their thickness being 5 ins., to match the width of the outer sections of the chords, while the counter braces, consisting of a single row of braces 4 ins thick, take bearings on the middle section of the chords of the same width.

The braces are designed of appropriate depths of section for transmitting with safety the maximum strains liable to occur under all probable combinations in adjustment of the tie members of the structure, and the assumed conditions of loading, neglecting the very material assistance rendered by the stiffness of the chords. The ends of the braces are framed to bearings notched in the chords, employing one or more notches per bearing, but nowhere are notches made of greater depth than 3 ins., and at critical points of rupture of the chords the notches are of less depth. A peculiarity of the form of truss adopted for the end arms, and one well taken advantage of by the designer, is the ample footings and thrust areas obtainable for the braces on the chords without serious reduction in the depths of the chords or requirement of increasing the scantling of braces beyond what is required for proper proportions to resist side bending. The main tie-bolts of the end trusses, like the braces, are designed for both cantilever and double-end bearing-action of the trusses, from either live or dead loading. As may be noted in the illustration, the bolts are in pairs, and passing through the spaces between the sections of the chords they are employed for suspending the road girders, which are also in pairs bolted together, thus affording broad and firm bearings in lateral support of the trusses. As lateral bracing, which is so essential to the stability of draw-span trusses, is not usually attainable excepting by portal bracing, additional lateral bracing afforded by other features of the truss will be appreciated.

The broad built-up chords coming close together at the ends of the draw span, permit of the omission of cumbersome portal bracing at those points, and while the center of gravity of each end truss is only slightly higher than it would be with parallel chords of the same depth of truss at middle of their span, in the truss described the center of gravity is thrown nearer to the center of the bridge and receives lateral support at relatively higher point of bearing on the tower posts than could be obtained with parallel chords.

For purposes of construction and repairs, the lower chords of the end-span trusses are provided with ¾-in. diagonal tie-bolt braces, which are supported on the road girders. These are, however, of little necessity when the floor joist and planking are in place. The floor joists are 3 × 10-in. cedar, 2 ft. 8 ins. centers, and are laid on the road girders parallel with the length of the bridge, spiked at every bearing. The planking is 3-in. cedar.

The turning machinery consists of the usual circular pier rack and duplicate pinions, with shafts of latter mounted on bearings secured to the turntable, the pinion shafts each extending up to the roadway planking, terminating with squared end for application of a capstan bar wrench operated by man power. The pier rack and steadying track are cast together in segments forming a rack of 14-ft. pitch diameter, with teeth 2 ins. pitch × 4-in. face, and circular track 13 ft. diameter × 3 ins. face. The pinions are respectively 8 ins. and 12 ins diameter.

The bridge is designed throughout for a live load of 90 lbs. per sq. ft., with an additional allowance of ¼ of both live and dead load to cover deterioration.

The estimated dead weights are as follows:

Draw span above turntable	63 tons
Turntable	9 "
Total weight on center	72 "
Weight of concrete above pile	88 "
Total weight on 32 piles (without assistance of bearing on bottom between piles), per pile = 5 tons	160 "

The total cost of the structure, including taking up of the old "jack-knife" draw, reconstructing approaches, piling and all other work, exclusive of engineers' services, was $3,759. Before deciding upon a wooden draw span, tenders were received for a number of steel draw-span structures, varying in design and costing from $5,500 to $22,000.

The less expensive of the designs offered provided for structures of one-third to one-half the weight of the wooden structure, but it was considered that aside from the difference of interest on investment, the cost of repairs and renewals would be very considerably in favor of a wooden bridge, especially in view of the fact that a steel draw span built of light riveted members presenting large area of inaccessible surfaces would rapidly deteriorate from corrosive action of the atmosphere, which is peculiarly severe at the location, due to its proximity to the ocean. The disadvantages of greater weight and greater power required for operating a wooden draw span were considered as more than compensated by adjustments available with a wooden structure, as against distortions of form of a riveted steel structure, due to variable expansion or accidents from navigation.

The new draw has been in very satisfactory use for over six months, and during the yachting season on Barnegat Bay has frequently been opened and closed over 100 times in a single day.

A number of observations recently made of the time required for all operations of opening or closing the draw by the bridge tender, unassisted, including the opening or closing of roadway gates at approaches, locking or unlocking the latches and opening or closing the draw 90° during a brisk wind, showed that 45 to 63 seconds were required, the average time being 55 seconds.

THE STABILITY OF SEWAGE EFFLUENTS FROM COARSE FILTERS.*

By H. W. Clark.†

All organic matter is presumably subject to change by bacteria. It may be in such a state or condition that bacteria change it easily, or it may be in such a condition that bacteria can change it but slowly. Most of the organic matter present in sewage is illustrative of the first condition, and that present in soil and loam is illustrative of the second condition. One of the objects of the following paper is to show that organic matter of the first class can be so changed by bacterial agencies, working under favorable conditions in sewage filters of coarse material, that this matter practically takes its place in the second class; that this change can occur in filters operated at high rates; and that this matter, when changed to a more or less stable condition, can, as far as the effluent itself is concerned, safely remain in the effluent instead of being strained or filtered out from it. That is, it will not under ordinary conditions rob this effluent of its dissolved oxygen and subsequently putrefy.

It was observed at the experiment station for a number of years that very turbid, poor appearing effluents from

*Abstracted from an advance reprint from the Report for 1901 of the Massachusetts State Board of Health.

†Chemist of Massachusetts State Board of Health, Boston, Mass.

filters of coarse materials operated at high rates of filtration would often remain without change for an indefinite period of time, and that the matter coming from these filters in suspension in their effluents and rendering them turbid to eventually deposit as sediment, or washed from them purposely at times to relieve clogging, was apparently in a stable condition quite different from the condition of the putrefying, ill-smelling matters in suspension in the sewage itself when applied to such filters. The cause of this was supposed to be that the organic matter in the sewage had been, while passing through these coarse filters, so thoroughly changed by the bacteria that the putrefactive stage had been passed, and the material was comparatively stable. This was first mentioned in the report of the Lawrence Experiment Station for 1895 (p. 469), and has been referred to frequently since. It seems probable that the organic matter, both that in solution and that in suspension, is worked over and digested by the bacteria in the filter, first by the anaerobic and then by the aerobic bacteria. By this process the matter is, in the first place, rendered unsuitable food for the anaerobic bacteria and perhaps toxic to them. When in this condition, however, it is suitable food for aerobic bacteria, which rapidly at first and then more slowly change it to this stable condition.

The term "secondary decomposition" has been used for a number of years by various authorities to describe the change occurring in the effluents of sewage filters whereby odors are developed and a blackening of the liquid occurs, owing to putrefactive agencies. The term is somewhat misleading, however, as implying decomposition by different bacterial actions from those active within the filter. Decomposition in its true sense is a change of organic matter in the presence of air, while putrefaction, which is generally meant by the above expression, occurs only in the absence of air. In this paper, therefore, care has been taken not only to use these terms distinctively, but also to show that the changes are very different, and also the cause for this.

Early in the year a series of samples of effluents was collected for study and examination from five of our filters of coarse materials operated at high rates of filtration, four of these being contact filters and one an anaerobic filter. These effluents were of varying degrees of purity as collected from the outlets of the filters, for the rate and manner of operation of the filters, together with the varying materials of which they were constructed, had allowed different stages of bacterial action and consequent purification of the sewage to occur within them. The results obtained from a study of these samples caused further studies to be made.

The effluents of Filters Nos. 82, 103, 137, 138 and 133 were taken for the first experiment. The construction and rate of operation of each of these filters at this time was as follows: Filter No. 82 was constructed of cinders and was operated at the rate of 400,000 gallons per acre daily; Filter No. 103 was constructed of small pieces of coke and was operated at the rate of 660,000 gallons per acre daily; Filter No. 137 was constructed of broken stones and was operated at the rate of 800,000 gallons per acre daily; Filter No. 138 was constructed of broken stones and was operated at the rate of 480,000 gallons per acre daily; and Filter No. 133 was constructed of broken stones and was operated continuously in such a manner that air was not admitted and only putrefaction occurred within it, its rate of operation being 2,700,000 gallons per acre daily. All were contact filters with the exception of Filter No. 133.

(Here follows a detailed account, with the results of chemical and bacterial analyses, of various experiments in which samples of effluent from the different filters were allowed to stand in gallon bottles, some of the samples being diluted with river water, and others not, and some of the bottles corked and others uncorked. Some of the bottles, also, were placed in an incubator, maintained at a temperature of 80° F., and samples examined daily for nearly five days.—Ed.)

SUMMARY.

The changes which go on in contact or other filters of coarse material are not always the same, but are dependent on the presence or absence of oxygen, and this in turn is dependent on various conditions, such as the character of the sewage, time of filling, time of contact and time of drawing off the effluent, etc. But that both anaerobic and aerobic actions usually go on in contact filters with the results described there can be no reasonable doubt. Further, that a limited period of anaerobic action, whether taking place within the contact filter or in the septic tank, is a favorable preparation of the organic matter for the subsequent action of the aerobic or oxidizing bacteria seems to be well proven. Thus we have within a contact filter usually both putrefaction and decomposition going on, and one or both of these processes is generally continued in the effluent. If the bacterial changes within the filter are very incomplete, the phenomenon of "secondary decomposition" (more properly called putrefaction) is the one to manifest itself in the effluent.

It is evident, moreover, from a study of all these results that the amount of organic matter determined as albuminoid ammonia and oxygen consumed in the effluent of a sewage filter constructed of coarse material, and operated at a high rate of filtration, is not a true index of the degree of purification of such an effluent, if we mean by purification the oxidation in the filter of the organic matter of the sewage to a more or less stable condition, and the production of an effluent which will not, when having free access to the air, putrefy. In order that such a stable effluent may be produced, it is only necessary that sewage shall have been for a comparatively short period of time in thin layers in contact with an abundance of air and that aerobic bacterial life shall have been active without the added straining out of organic matter obtained by sand or other filters of fine material. Such an effluent will show good nitrification and the presence of dissolved oxygen when running from the filter, irrespective of the amount of stable organic matter that it contains. These effluents, produced either by intermittent-continuous filters or by the best of contact filters, show little tendency to change when excluding air, and maintained at summer temperature for a considerable period. When mixed with water containing oxygen they invariably improve in quality. Even much poorer effluents improve when under the conditions last named, although they decompose and putrefy under the first-named conditions.

If such an effluent, showing good oxidation and nitrification occurring in the filter, contains dissolved oxygen, and habitually retains this dissolved oxygen, for a considerable period, it is fairly certain that putrefaction will not occur in it under ordinary conditions, as when exposed to air. Slow oxidation may and probably will occur, this latter action improving the effluent without producing odors. This is abundantly proved by the experiments above described. If, on the other hand, the effluent as it runs from the filter does not contain dissolved oxygen, or if the oxygen present disappears with comparative rapidity, it may be taken as assured that such an effluent will putrefy eventually unless mixed with a considerable volume of water containing dissolved oxygen, even though it contains a smaller amount of organic matter, determined as albuminoid ammonia and oxygen consumed, than other effluents of the character just described, and even though a considerable amount of nitrates is at first present.

In the purification of untreated sewage by sand filtration there is upon many of these filters a constant tendency for surface clogging caused by the accumulation of the coarser and more stable organic matter of the sewage, and in order to keep these filters in operation, this matter either has to be scraped from the beds from time to time, or plowing with periods of rest has to be resorted to. With an intermittent continuous filter of broken stone, on the other hand, much of this coarse organic matter passes through the filter, as already stated, and appears in the effluent, and surface clogging does not occur. Moreover, as this matter passes through and encounters aerobic conditions, it is, as illustrated by the experiments, oxidized to an innocuous condition, and can be easily strained from the effluent at very high rates, if desired, leaving this effluent well purified, clear and highly nitrified, or about equal to the average effluents of sand filters, and produced by a rate of filtration many times as great. It is, of course, unnecessary to dwell here upon the fact of the desirability of producing filter effluents as free from the matter in suspension as possible, such as can be obtained by sand filtration, notwithstanding the fact that turbid but nevertheless fairly stable effluents can be produced by rapid methods of filtration.

STUDIES OF INCUBATION TESTS.

Studying the results of the many determinations of oxygen consumed from permanganate that have been made during these various experiments, we find (1) that the oxygen consumed from permanganate invariably decreases in effluents which are in such condition when collected that they undergo slow oxidation only; (2) that with effluents that finally putrefy the amount of oxygen consumed generally decreases at first, if any amount of nitrates and dissolved oxygen is primarily present in the effluent, to increase later when putrefaction occurs; (3) that in one instance, when the effluent of anaerobic Filter No. 133 was incubated at 80° F. for five days, the oxygen consumed increased only very slightly, although the change in the appearance and odor of the sample was very marked, owing to the putrefaction occurring within it; and (4) that in one instance, although the amount of oxygen consumed increased largely in this effluent when it was kept for a period of eleven weeks, yet during the first three weeks it decreased. These results, taken in connection with the complete analyses of the samples in each series, seem to throw some doubt upon the significance of the so-called five-day incubation test with the determination of oxygen consumed only, used to determine the stability or instability of the organic matter of the effluents of sewage filters, that is, to determine their liability to undergo the so-called secondary decomposition. This determination is very much depended upon, however, in England, to show the character of the effluents of sewage filters, as being a much shorter way than complete analyses of these effluents. It would seem, however, that in most instances a determination of the dissolved oxygen present at the beginning and the end of the period of incubation, together with observation of the change in appearance of the sample, if any occurred, would be a more satisfactory simple test.

Owing to the results obtained in this previous work a series of incubation tests was undertaken, in connection with complete analyses of effluents of filters of various kinds, producing effluents of varying degrees of purification.

Studying these results as carried on with 21 samples of effluent, we find only three instances where the oxygen consumed from permanganate increased at the end of five days' incubation, although in 10 of the 21 effluents examined there was no dissolved oxygen present at the end of the period, and in two of the samples—both of the same effluent, however—there was no dissolved oxygen present at the beginning of this period. Several of these effluents, showing less oxygen consumed at the end of five days, putrefied, as evidenced by their change in appearance and by the development of gas and odors. In a number of them secondary decomposition occurred—if we use the word "decomposition" in its true sense, meaning change of organic matter in the presence of oxygen—although odors did not develop in these samples, as the change was oxidation instead of putrefaction.

THE WATER-TUBE BOILER IN THE AMERICAN MERCANTILE MARINE.*

By William A. Fairburn.

HISTORICAL.—The water-tube boiler is not a new form of steam generator, but an old one resurrected, and it is a peculiar fact that all the successful water-tube boilers in the market to-day have as a prototype some early form of experimental steam generator. The Goldsworthy-Gurney boiler of 1827 is the forerunner of such types as the Thorneycroft and Normand; the double tube class of boilers of the Niclausse and Durr types originated with the Perkins boiler of 1832, and the Babcock & Wilcox and D'Allest boilers have as their prototype the Stevens boiler of 1805. It is gratifying to know that the pioneer marine water-tube boiler was built in our own country, Col. John Stevens fitting such a boiler in a small Hudson River steamboat a century ago. Water-tube boilers were tried, with indifferent results, in merchant vessels built on the Clyde in 1857, and again in 1870. The Belleville boiler was fitted in the "Biche," of the French Navy, in 1856, and the first installation of this type of boiler in a merchant vessel occurred in 1884, the "Ortegal," of the Messageries Maritimes Co., being so fitted. The performance of the boilers in this vessel was considered so satisfactory that several other vessels of the same fleet have been fitted with them. Thorneycroft boilers were used successfully in England in 1882, and from 1890 up to the present time the water-tube boiler has been steadily growing in favor. High speed with its accompanying high pressure and steam economy has done much to hasten its adoption. The first important installation of Babcock & Wilcox boilers in a merchant vessel occurred in 1891, when the "Nero," of the Wilson Line, was so equipped. The first transatlantic vessel equipped with water-tube boilers was the "Martello," fitted in 1900 with the same type of boiler. Since that time several British vessels of the Wilson, Peterson-Tate and Allan lines have been similarly equipped, the Babcock & Wilcox boiler being the only water-tube steam generator in use to-day on ocean-going vessels of the British mercantile marine. Seven years ago two Babcock & Wilcox boilers were fitted in the Lake steamship "Zenith City," and at about the same time the same type of boilers—eight in number—were installed in the coasting steamship "La Grande Duchesse." Whereas the boilers in the Lake steamship were considered satisfactory, and many other Lake vessels were, as a result, equipped with similar boilers, the installation on the Plant Line steamship was pronounced a failure, and Scotch boilers finally replaced the water-tube boilers. In 1894 Belleville boilers were fitted in the Lake steamships "North West" and "North Land," but after a most trying period, in which every conceivable experiment was tried to make these boilers successful, they were finally replaced by Scotch boilers. The Niclausse boilers built in this country have only been fitted as yet in naval vessels, but the two large Transpacific steamships, building for the Great Northern Steamship Co., will be equipped with this type of boiler.

At the present time the results obtained from the use of water-tube boilers in the American mercantile marine have not been entirely satisfactory. The only three large installations made on American steamships have been branded failures, Babcock & Wilcox boilers being condemned in one vessel and Belleville boilers in the other two. Nevertheless, the writer is convinced that a good form of water-tube boiler can be used successfully at the present time in the mercantile marine, provided the space and arrangement of the ship is made to conform to its requirements and the boilers are properly operated when installed. The personnel of the Northern Steamship Co.,

*Extracts from a paper read at the tenth general meeting of the Society of Naval Architects and Marine Engineers, held New York, Nov. 20 and 21, 1902.

owners of the Lake passenger steamships "North West" and "North Land," is the same as that of the Great Northern Steamship Co., and although the Belleville boilers in the two large Lake passenger steamships proved very unsatisfactory, yet these people preferred water-tube boilers of the straight-tube free-circulation type for the large sea-going vessels which are now being constructed for them at New London. It has been said that positive progress cannot be made without failures, and well that it is so, for bitter experience gained by failure builds a solid foundation of facts and truths, upon which is established ultimate success. The water-tube boiler of suitable type has a promising future before it, and there seem to be many good prima facie reasons for expecting its adoption in the mercantile marine in the immediate future. Great care and caution must, however, be exercised in the design of boilers adopted, and in the arrangement and operation of same on board ship.

FEATURES TO BE CONSIDERED IN THE DESIGN OF A WATER-TUBE BOILER SUITABLE FOR MERCHANT VESSELS.—A water-tube boiler to prove durable, reliable, give excellent results in the mercantile marine, and grow in favor as a result of its merit until it shall finally displace the well tried and favorite Scotch fire-tube boiler should possess the following essential features:

(1) All tubes should be absolutely straight and of uniform length. They should be of seamless drawn steel or nickel steel, very uniform in quality, and as near non-corrosive as is possible, with a ratio of length to diameter not exceeding 30 diameters. These tubes should be submerged and be placed on an angle of about 10° from the horizontal. The boiler should be sectional, with front and back headers, or a compound front header with circulating tubes within the generating tubes. The tubes should be not less than 3 ins. diameter, more preferred, and have a thickness varying from No. 5 to No. 8 B. W. G., according to size and location.

(2) The steam drum should be placed at the front of the boiler with its center square with the tubes. The water level should be at the center or a little below the center of the drum. The drum should be not smaller than 45 ins. diameter when space permits. If back headers are fitted, the steam discharge to the drum should be horizontal and connect to the drum at the water level. The interior of the drum must be made accessible. No part of the drum should be exposed to the hot gases.

(3) The headers should be of wrought steel. No cast metal should enter into the construction of any pressure part of the boiler. The proportioning of the relative areas of the headers, uptake and down cast, determine the capacity of the boiler and regulate the circulation.

(4) The water circulation must be active and positive and follow a defined path. The more rapid the circulation of water over the heating surface the greater the evaporation.

(5) The furnace or combustion chamber should be high, at least three ft., so as to thoroughly mix the gases before coming in contact with the heating surface.

(6) All parts of the boiler exposed to the gases or pressure, particularly the exterior and interior of tubes, should be accessible for cleaning and repairs. It is necessary to keep the outside of tubes free from soot and fine ashes, the latter being especially destructive when moisture, such as is obtained from an attempt to clean from the outside with a steam jet, is present. A boiler composed of tubes that can be drawn from the front for examination possesses great merit. Expanded joints are preferable in many ways, but the necessity of keeping a boiler clean is of vital importance.

(7) The boiler should be easily drained without resorting to syphoning or the withdrawal of elements or individual tubes.

(8) The headers should be of corrugated form, the tubes being staggered with no straight path for gases between the same.

(9) There should be a mud drum or receptacle arranged for the reception by gravity of solid foreign matter separated from the feed water.

(10) The path of the gases leaving the furnace or combustion chamber should be approximately square to the tubes, and such that all the heat possible is abstracted from said gases before they enter the uptake. Efficient baffling can only be determined by experiment, and the nature and extent of the baffling will vary for the various rates of combustion. Proper baffling with reasonably good firing will eliminate the criticism of high stack temperature.

(11) The air supply to the fires and furnace must be ample, but not excessive. Air supplied under pressure over the fires from all four sides of the boiler may be found desirable. Distance between fire bars is of great importance. Hot air supply and induced draught may be found exceedingly efficient for water-tube boilers.

(12) The boiler should never be placed with steam drums forward and aft, and tubes athwartships in any ocean-going vessel, or in any vessel navigating rough waters.

(13) The boiler should be capable of being built in any well equipped boiler shop. The parts should be simple and of uniform construction, with as few different parts as is possible. A large number of spare parts to be constantly carried at sea is undesirable. The boiler should be built so that it can be readily repaired by the vessel's own staff, no extra skilled labor being necessary.

(14) The boiler should have a larger ratio of power to unit of floor space and volume.

(15) The boiler must stand forcing and maintained severe service.

(16) The casings should be air tight, built of heavier material than is usually used, and well insulated throughout in a manner that will stand the test of time.

(17) Dry steam must be generated and the steam should have free and unobstructed escape to a steam dome placed at the center of the drum, from which the dry pipe leads to the main steam pipe. No separators or reducing valves should be permitted, having for their object the drying of steam.

(18) The feed arrangements should be simple and require no elaborate automatic apparatus.

(19) The steam should be generated at a pressure equal to the working pressure of the engines. The boiler must be suitable for high pressure.

(20) No screwed connections should be exposed to the gases.

(21) Economizers placed in the uptakes are very efficient, but their inaccessibility and great cost of upkeep does not warrant their adoption. The feed water must, however, be injected into the boiler at a very high temperature.

(22) The use of induced draught and air heaters, permitting a low stack temperature, making the installation independent of climatic conditions and causing a cool fire room, is considered favorable for a marine water-tube boiler installation.

(23) The pressure on feed lines should not exceed the boiler pressure, and the feed system should be such that the amount of air in water is reduced to a minimum.

(24) Mechanical stokers or oil fuel will probably be used and great gains result from better combustion, more regular uniform heat, constant steam pressure, and the prevention of loss of heat caused by frequent opening of fire doors.

(25) The boiler must have absolute freedom for expansion.

(26) The boiler must respond quickly to any sudden or unusual demand for steam and carry a steady water level.

(27) The weight of the boiler should show approximately the same relative advantage over the weight of Scotch boilers as the water-tube boilers discussed in this paper. The parts should be light and easy to handle.

(28) The thermal efficiency of the boiler must be equal or superior to that of any fire-tube boiler tested by the same unprejudiced engineer under exactly similar conditions.

(29) The boiler must be capable of showing good results when burning inferior coal.

(30) A tube should be renewed or plugged without removing any other tube or pressure part, or cooling down the boiler, other than by blowing off the pressure. The component parts should be independent of one another, so that the removal and repairs of one part do not disturb other parts.

(31) Sufficient water should be carried in the steam drum to give the boiler a period of about twenty minutes before the water in said drum is evaporated, provided the feed is shut off and the boiler continues steaming easy under the usual natural draught conditions, burning about 15 lbs. of coal per sq. ft. of grate surface per hour.

(32) The steam space in cubic feet should be about equivalent to the grate surface in square feet.

(33) The ratio of heating surface to grate surface should be not more than 40 to 1, and possibly less for natural draught conditions.

(34) Suitability for rapidly raising steam.

(35) Must be capable of being built in large units, and if worked entirely from the front, or front and back, side battery construction may prove advantageous.

(36) Should consist entirely of cylindrical components with spherical ends, all parts being self-sustaining without staying.

(37) The cost should be no more than that of a Scotch boiler.

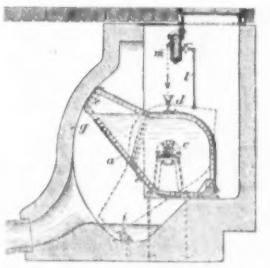
COST OF BOILERS.—It is difficult to write on this subject without quoting comparatively from propositions received from competitive boiler makers, and this, of course, cannot be done. Scotch boilers can be bought in the United States to-day cheaper than water-tube boilers of the type herein discussed. Wrought steel or high-grade semi-steel headers, seamless drawn tubes instead of lap-welded, heavier settings, thicker tubes, larger drums and more insulation have had the effect of increasing the price of water-tube boilers. A cheaper grade of water-tube boiler could undoubtedly be built to successfully compete with the fire-tube boiler in regard to price, but it must be remembered in these comparisons that only the finest quality of water-tube boilers are considered, whereas the construction, weight and quality of the fire-tube boiler is a very variable quantity. Scotch boilers can be built to-day for about $3.30 to $4.00 per sq. ft. of heating surface, whereas water-tube boilers cost from $4.00 to $4.40 per sq. ft. The price per lb. on several propositions received varies from 10.65 to 12.2 cts. for Scotch boilers, and 15 to 19.7 cts. for water-tube boilers. The price per sq. ft. of grate surface, based on these same quotations, varies from $129 to $150 for Scotch boilers, and $151 to $168 for water-tube boilers. There is very little difference between the price asked to-day for the Babcock & Wilcox, Niclausse and Belleville boilers, and these prices usually run about 15% over the prices asked for Scotch boilers. The Niclausse boiler is probably the most expensive of the trio of water-tube boilers to build, but this fact is not noticeable in comparing the selling prices. In a few years the water-tube boiler will be produced as cheaply as the Scotch boiler, and if lap-welded tubes were used in water-tube boilers, the same as in Scotch boilers, then there is no doubt that even now the water-tube boiler could be built to sell as cheaply as the fire-tube boiler.

CONCLUSION.—The water-tube boiler is the boiler of the future, and its ultimate universal adoption is positive. An ideal or entirely satisfactory water-tube boiler has not as yet been produced, but such boilers as the Babcock & Wilcox and the Niclausse will probably prove the forerunners of a type of boiler that will fulfill the necessary essentials and obtain the confidence of designing and operating engineers. Mechanical stokers and liquid fuel will assist the water-tube boiler in its progress and advance into favor, and although the former will be used extensively in stationary plants, its application to marine work will be somewhat limited, for fuel oil will become very popular afloat and entirely supplant coal in many trades and on many seas.

A NEW GERMAN AUTOMATIC FLUSH TANK.

The "Centralblatt der Bauverwaltung" illustrates in a recent issue a form of automatic flush tank for flushing sewer laterals, which has just been patented in Germany. We reproduce the sectional view, shown herewith, for comparison with the styles of automatic flush tank used in America.

The construction of the new device will be quite clear from the accompanying drawing, with perhaps a few words as to its action. The tilting tank is open at its narrow upper end, and is filled through a small funnel at the top. It is pivoted in such a manner that it tips to the discharging position when filled beyond a certain level, while when emptied it tilts back automatically to the filling position. Buffers are provided to absorb the shock at both ends of the movement. The water from the street service pipe passes first into a small closed auxiliary or equalizing receiver, vertically above the tank. From the nozzle of this receiver it falls into the funnel below.



It will be observed that while the tank tilts to its discharging position, its mouth is closed by the curved wall of the containing chamber; thus the entire content of the tank is discharged very suddenly. This object is also favored by the shape of the tank itself. The patent on the device is controlled by the Geiger Sanitary Appliance Works, of Karlsruhe, Germany.

TWIN SETTLING RESERVOIRS are being built at Marietta, O., to improve the quality of the Ohio River water, which is at present pumped practically direct to the mains. The reservoirs will have a combined capacity of 21,000,000 gallons, which, with the present average daily consumption, is more than ten days' supply. They are to have an area of some four acres, and are to be 20 ft. deep. The excavation is now being done by the city itself, at a reported cost of from 15 to 20 cts. per yd., which, it is claimed, is much less than a contract could be let for. The bottom and sides of the reservoirs are to be paved or concreted, according to the relative price of material next spring, when it is proposed to finish the reservoirs. The water will be pumped direct from the river to these reservoirs through 11,200 ft. of 24-in. cast-iron pipe, for which the contract has not as yet been let. From the reservoirs the water will be supplied to the city by gravity. It is expected that the period of subsidence allowed and the opportunity given for selection of the water pumped will result in a comparatively clear supply of water for the entire year, something which the present system does not even attempt. Bonds for $100,000 have been issued for the improvement, but it is stated that this sum will not carry the work to completion.

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ADVERTISING RATES: 20 *cents a line. "Want" and "For Sale" notices, special rates, see page XXIV-XXIX. New copy for standing advertisements should be received one week in advance of publication; new advertisements, Monday morning. The pages containing "Want," "For Sale" and "Proposal" advertisements are held open until Wednesday noon.*

The treaty of peace signed on board the U. S. battleship "Wisconsin" on Nov. 21, between the Colombian government and the revolutionists is of particular interest at the present time because of the bearing it may have on the perfecting of the Panama Canal concessions to the United States. One article of the treaty provides for reforms in Colombian finances to be carried out with the money to be received from the canal concessions. This well illustrates the fact that the success of the pending agreement between Colombia and the United States is quite as important to Colombia as it is to this country. If anything it is of more importance, for the United States has still the Nicaragua route to fall back upon in case the Colombian officials go too far in their demands.

We have, however, excellent authority for saying that while there may be more or less hitches in the negotiations, the final success of the United States in obtaining the desired authority from the Colombian Government for the Panama Canal work is practically certain. Colombia could better afford to cede the strip of territory to the United States outright as a free gift than lose this opportunity of having the canal constructed. There may very likely be a renewed expression of sentiment in Congress when it reassembles in favor of the Nicaragua route; but its chief effect will probably be to awaken the Colombian negotiators to the danger of losing the prize so nearly within their grasp.

We believe that it is possible by means well known to the hydraulic engineer to reduce the water consumption in the Boroughs of Manhattan and the Bronx by 50%.

So says the "New York Times" in commenting upon the engineering commission which is to report on an increase in the water supply of Greater New York. If our contemporary had said that more than 50% of the water supply of New York city is wasted, it would have been near the truth; but it is a far cry from that fact to a reduction of the water consumption by 50%. This subject was thoroughly covered by the investigations of well-known experts at the time of the Ramapo investigation, two years ago. We may refer particularly to the report of Mr. John R. Freeman, M. Am. Soc. C. E., in Engineering News of April 19, 1900. The consensus of expert opinion favors waste-restricting measures, the more the better, but recognizes the fact that in New York city these measures can only avail to tide over the city through a period of scarcity before any new source of supply can be made available. Waste prevention cannot be a substitute for an increased supply, as our contemporary suggests; nor can we accept its suggestion that the increased supply is a question "admitting of leisurely consideration." The real fact is that New York cannot act too promptly if it would avoid the possibility of a water famine in the near future.

The most widespread increase in the wages of railway employees that has ever been recorded, so far as we recall, has been started by the recent action of the Pennsylvania Railroad Co., in announcing a 10% increase in the wages of all its employees receiving less than $200 per month. The action was taken voluntarily, which speaks all the more for the good sense and sound business ability of the Pennsylvania's officers. The advance is justified on the one side by the increase in the cost of living which has taken place during the past few years, and on the other side by the enormously heavy traffic which the Pennsylvania lines are now moving and the industry, vigilance and faithful service which is demanded of the operating force that has to cope with it.

The Pennsylvania's action has been followed by a number of other large railway systems, so that the increase bids fair to affect a very considerable percentage of the railway employees of the United States.

A good deal is being said concerning the probable effect of this wage increase upon future rates of dividend. The stock operators who have marked up prices of many railway shares beyond the point which reasonable expectations of future earnings can justify are naturally apprehensive. On the other hand the general public, including, we doubt not, a large proportion of the employees who will benefit by this advance, look upon the increase as a mere bagatelle to the railway companies. "They will never feel it," would be probably a fair expression of popular opinion.

It may be of some service, therefore, to show just what an all-around 10% increase in employees wages would cost the railways of the United States. Fortunately the accurate official statistics of the Interstate Commerce Commission enable a statement to be made with almost absolute accuracy. Taking the report just at hand for the year ending June 30, 1901, we find that the total payments to the railway employees of the United States in that year were $610,713,701. In the same year the holders of railway bonds received interest amounting to $252,595,000 and the stockholders received $131,626,000 in dividends. Thus those employed in the railway service received in wages and salaries about five dollars for every three dollars paid to railway stock and bond holders.

Suppose now that all the railways in the United States were to make an all-around increase in wages of 10%. Deducting from the above total of $610,713,000 the salaries paid to officials we have in round numbers about $590,000,000 as the total wage payments; hence a 10% increase in this would mean an annual expense of $59,000,000 to the railway companies. Had this payment been made in 1901, it would have reduced the surplus remaining in the treasury of the companies, after paying all expenses, to about $28,000,000 instead of $87,000,000, its actual figure.

Thus it appears that the railway companies of the United States last year, taken as a whole, did have enough surplus after paying all their expenses, interest and dividends to have paid a 10% increase in wages.

Let us see how things would have gone with them, however, had they attempted to pay such an increase in 1897. In that year the total wage payments were about $450,000,000, hence a 10% increase would have cost the railways about $45,000,000. In that year the railways of the United States paid out $87,000,000 in dividends and had but $6,000,000 surplus left afterward. Thus if a 10% increase had been made to railway employees throughout the United States in 1897 it would have cut down nearly half the dividends paid to railway stockholders.

The moral of the above statistics is easy to read. The present prosperous times justify such an increase in wages by railways carrying heavy traffic, as is now being made, and it is a better and wiser use of present surplus earnings than an increase in dividend rates or extensive stock watering manipulations, such as present stock market prices seem to point toward. On the other hand it does not follow that such an increase can be maintained throughout when the next season of hard times and scanty traffic appears.

The statement above made that the railway employees receive $5 for every $3 paid to railway security holders really gives an inadequate idea of the extent to which railway earnings go directly to pay wages, because of the sums paid by the railways for the purchase of materials, the bulk goes directly to pay wages of labor. A railway purchases locomotives, for example, instead of building them in its own shops, and labor receives the wages for the work of building them as well as of making the raw material used in their fabrication. It would be fair, we believe, to take 80% of the operating expenses of railways outside of wages as going directly into the pockets of wage earners. On this basis the wage earners of the United States in 1901 received fully $925,000,000 from the railway companies. There is still to be added to this, however, the amount spent by the railways on permanent improvements, the great bulk of which goes to pay wages. When this is included we have a total of fully $950,000,000. In other words, of every dollar which the railways earned in the prosperous year of 1901, sixty cents went to pay wages.

One of the most frequent causes of failure of many classes of engineering work is that after being designed and constructed in accordance with the best scientific knowledge of the day they are turned over to the management of some person who knows nothing whatever regarding their operation. This is particularly true of municipal works, and of none is it more notable than of sewage purification plants. This is all the more discouraging, both because of the poor results thus likely to be obtained at each disposal works and because such ignorant, if not incompetent, persons cannot for years, if ever, contribute anything worth while to the general fund of knowledge of the art. As Mr. John W. Alvord well suggests, in a paper on "The Proper Operation of Sewage Purification Plants," abstracted in this issue, it would be well indeed if the operation of sewage purification plants were entrusted for a year after construction to the engineer responsible for their design. Of course, this need not mean anything like daily, or even weekly visits, after the first few weeks. In fact, there might be many instances where practically all the supervision could be deputed to an assistant familiar with the works, or even to some outside person of proper attainments; for after all the main thing is trained supervision. Looking at the subject from the point of view of amassing and imparting information to others it may be observed, as did Mr. Alvord in a portion of his paper omitted from our abstract, that data regarding full-sized plants in operation are of more value than those from experimental stations and working plants in miniature. This being true, we feel sure that a hearty welcome will be given to Mr. Alvord's paper, based largely on his personal observations of plants which he has built, some

of which have been closely watched by him since they were put in operation; one being under his direct supervision. On one point we think Mr. Alvord has perhaps gone a little further than he intended, and that is in belittling the value, or need, of sewage analyses. We heartily agree with what he says regarding the folly of basing conclusions on a few scattering analyses, and of placing much reliance on mere percentages of organic matter removed, but frequent analyses, carefully made and digested, cannot fail to be of great value to those who know how to interpret them. Moreover, we believe the day is coming when the larger purification works will be placed in charge of chemical engineers who can make their own analyses, while the smaller ones will have the benefit of state supervision, accompanied by more or less frequent but regularly recurring analyses.

The announcement in press dispatches that a monument has been erected "in an out-of-the-way place," in Bartholomew Co., Ind., to mark the center of population of the United States, as determined from the last Census, reminds one of some keep-off-the-grass signs; population and grass alike being conspicuous by their absence from the vicinity of the monument and the signs. In fact, the press dispatch says that as the monument in question "cannot be seen from the highway, a marker has been placed there, directing the passerby to the spot." In view of the inaccuracies that must enter into a computation of the center of population of a country like this, the monument might as well have been placed on the highway as at some remote point in the fields or woods.

Some very practical conclusions regarding sewage treatment seem to be warranted by Mr. H. W. Clark's paper on "The Stability of Sewage Effluents from Coarse Filters," abstracted elsewhere in this issue. The most important of these is that where effluents are to be discharged into a stream not used for domestic purposes, that is, where a nuisance from odors of putrefaction is the only fear, rapid filtration of sewage may sometimes suffice, without an effort to remove the bulk of the matter in suspension. In other words, bacterial action is carried to such a point in the filter beds that, provided there be enough available oxygen in the stream, the completion of the process of decomposition may be allowed to take place in running water. The filter beds reduce the sewage to a condition where it may as readily be decomposed by bacteria in water as in the soil. Another conclusion, of chief value to analysts and interpreters of analyses, is that the incubation tests upon which so much reliance is placed in some quarters, particularly in England, are not so significant as has been thought as regards the likelihood of secondary decomposition, or, more properly, putrefaction.

The tightness with which the municipal purse strings are often held when sanitary improvements are under consideration, and the relative freedom with which money is voted for some object that appeals to popular sentiment, is well illustrated by the following extract from a letter recently received by us:

> From the note below you may judge that we have a queer set of people in this section. At the last election Columbus (Ohio) voters carried a $250,000 bond issue for Franklin county for a memorial building to the soldiers and sailors of the several wars. Within the last few years several bond issues for the improvement of the water supply and sewer system have been defeated. As the water supply is notoriously polluted and the sewerage very inadequate, and the sewage a nuisance, it is evident that the majority of the Columbus voters think much more of the memory of the heroes of the country than they do of the lives of their relatives and neighbors. Better that the memorial building be a crematory for the safe and economical disposal of the murdered than a tombstone for the long departed.

The "Waste Heat" engine, described on another page of this issue by Professor Miller, of the Massachusetts Institute of Technology, is an interesting departure in power plant engineering, and the experiments with it are certainly worth careful attention, although as a matter of fact the idea of the engine is by no means new.

The same principle was exploited by the French inventor Du Trembley as long ago as 1847, and eight steam vessels were fitted with his system. Sulphuric ether was used as the auxiliary fluid instead of sulphur dioxide, and the invention finally failed because of the danger from fire and explosion from the use of so inflammable a substance.

In the early '70's a system similar to Du Trembley's, but using carbon bisulphide instead of ether as the auxiliary working fluid, was extensively exploited in the United States by the Ellis Vapor Engine Co. Here again the same difficulty of danger from the inflammable and explosive vapors was encountered, and after a serious explosion in the Poole & Hunt works at Baltimore, one of the licensees for the manufacture of the engine, the system was abandoned.

We take the above facts from a valuable paper by the late Geo. H. Babcock entitled "Substitutes for Steam," in the "Transactions of the American Society of Mechanical Engineers;" Vol. VII., p. 680. A series of papers on the same subject by Dr. Robert H. Thurston is now appearing in the "Journal of the Franklin Institute," and may profitably be consulted by those who desire to investigate this field of invention.

As Professor Miller shows in this issue, the binary vapor or multiple vapor engine rests on a sound theoretical basis, and does actually offer large possibilities in the direction of higher heat engine economy. The practical question is whether the difficulties in operation will be in the future as they have in the past, sufficient to counterbalance this economy.

That these practical difficulties will greatly restrict the field of any invention of this sort is clearly evident. No volatile working substance is known, for example, which would be deemed safe to use with an engine in the hold of a vessel. Again, in all power plants of small size, no such complication is likely to find favor, since the total saving effected would be too small to make it worth while.

In large-size stationary steam plants, however, the binary vapor engine has at least the chance of success, and a much better chance than it had thirty or twenty or even ten years ago. The handling of noxious gases in working cylinders and condensers is no longer a novelty. The progress in the art of artificial refrigeration has made it familiar to thousands of engineers, and there need be no more difficulty in using ammonia or sulphur dioxide in a cylinder to develop power than in the compression cylinder of a refrigerating machine.

We do not mean to say that an ammonia or sulphur dioxide attachment will be a wholly desirable adjunct to the engines of an electric power station, for example, and we appreciate the fact that those responsible for the continuous operation of such stations without interruption will naturally be inclined to oppose such an innovation. Nevertheless, the possibility remains of making a large economy, and by measures for isolating the ammonia or sulphur dioxide apparatus from the rest of the plant, it may be possible to overcome objections and bring the system into commercial use.

THE CONSTRUCTION OF SUSPENSION BRIDGE CABLES.

The supporting cables of modern suspension bridges of long span are made of steel. They are either chains of connected eye-bars, or cables formed of parallel wires, or twisted wire ropes. Practically all suspension bridges of long span which have been built or planned for construction for many years have had parallel wire cables. This construction, however, has admitted faults, and, consequently, its critics, some of whom have boldly contended that the chain cables or twisted wire ropes of special design and material could be made to show superior qualities. Perhaps the latest example of this occasional attempt among engineers to break away from the generally accepted conventions of cable construction is the plan of Mr. Gustav Lindenthal, M. Am. Soc. C. E., Commissioner of Bridges of New York city, to use forged eye-bars of high-grade steel for the cables of the new 1,600-ft. span Manhattan Bridge across the East River.

Mr. Lindenthal's plans are not yet fully developed, and until they are he declines to discuss them; until then, also, specific criticism is impossible. It will, however, clarify matters somewhat for future discussion to review briefly the history of suspension bridge cable construction and particularly those parts of it which record the attempts of modern engineers to improve upon the parallel wire cable.

Great Britain possesses no modern suspension bridge of the first magnitude when measured by the great structures of America, or even by those of continental Europe. Previous to 1850, however, English engineers designed and executed several suspension bridges of wide fame. Even yet the names of the Menai, Lambeth, Clifton and Chelsea bridges, belonging to this early period, are more familiar to bridge engineers than those of many structures of later date and greater magnitude. All of these bridges were highway bridges, and all except the Lambeth had eye-bar cables of wrought iron. Doubtless Telford's Menai Bridge is the most far-famed of these structures. Its span was 580 ft., while that of the Chelsea Bridge was only 333 ft., and that of the Lambeth only 298 ft. The span of the Menai Bridge was, however, exceeded by that of the Clifton Bridge over the River Avon, near Bristol, which was completed in 1864.

In magnitude the Clifton Bridge heads the list of English suspension bridges with its span of 702¼ ft. It is of more particular interest in the present connection, however, for the methods adopted in erecting its eye-bar cables, a problem which the builders of the Manhattan Bridge have before them multiplied many magnitudes, should eye-bar cables be used for its 1,600-ft. span. The following account of the erection of the cables for the Clifton Bridge is abstracted from a paper by Mr. W. H. Barlow, one of the engineers, read before the Institute of Civil Engineers in 1867. Under each set of three chains there was constructed a footway suspension bridge using wire rope cables. Above this staging another rope was fixed for the purpose of carrying two light traveling frames suspended on wheels, which were moved as required by light ropes and by means of which the chain links were taken from the piers to the men engaged in erecting the chains.

The chains were commenced at the anchorage plates at each end simultaneously, the lowest of the three chains being put in first. At the anchorage plates the whole of the links, twelve in number, were inserted, then eleven, ten, nine, eight, and so on until the chain was diminished to one link, after which it was continued at one link and two links alternately until the two halves met at the middle of the span. The suspended staging was designed to carry the weight of the center portion of the chain, consisting of one and two links alternately, until the center connection was made, when the chain was made to take its own weight by removing the blocking underneath it. The next operation was to add the remaining links to complete the chain. The suggestions which may be gleaned from the Clifton Bridge as to methods of erecting chain cables are about the only thing that English practice offers to the builders of the Manhattan Bridge.

In continental Europe the suspension bridge work of German engineers has in recent years been of a very high character and unusually fruitful in innovations. The oldest German suspension bridges were all chain cable bridges of short span, and they have all, we believe, given way to modern truss structures. It is only to the designs of recent years that the engineer can look for instruction in cable construction. In the Budapest Bridge competition of 1892 the first prize was awarded to a suspension bridge designed by Mr. J. Kuebler and having a span of 1,036 ft. The main cables of this design were of parallel wire construction, their only novelty, broadly speaking, consisting in the fact that they ended at the towers in a socket connection and that two similarly connected anchor cables carried the pull of each main cable back to each anchorage. The details of this construction were illustrated in Engineering News of Nov. 15, 1894, and will not be considered further here. Although Kuebler's design was awarded first prize it was not executed.

In 1894 the same engineer submitted a design for a suspension bridge of 696 ft. span in the competition for a bridge over the Rhine at Bonn. This design, like its predecessor, won a prize, but was not executed. The chief point of interest in connection with it is that in the same competition the Nuremberg company submitted a design for a chain bridge of 738 ft. span, which enabled a comparison of weight between the two forms of cable construction. The Kuebler bridge weighed 7.4 tons per lineal meter, while the chain bridge weighed 11.8 tons per meter. In the Worms Bridge competition the Nuremberg company again entered the field with a chain bridge, this time with the interesting innovation of a chain made of nickel steel. For the nickel steel links of this chain Krupp had guaranteed, it is said, a tensile strength of 44½ to 54 tons per square inch, with a "limit of proportionality" of 36½ tons and a ductility of 15 per cent. The design called for a span of 310 m. (1,017 ft.). This bridge undoubtedly ranks as the boldest attempt to employ chain cables up to the time of its design, and gives us all that Germany has to furnish in the line of chain cable construction.

In the line of wire rope cables the work of German engineers has furnished two interesting examples in the Langenargen Bridge in Switzerland, designed by Kuebler and Liebbrand, and the design of the Nuremberg company for a bridge across the Rhine at Cologne. The cables of the Langenargen Bridge are each 5 3-10 ins. in diameter and each consists of six wire ropes each formed of 37 wires 15-64 in. thick and a core of 37 wires ¼-in. thick. The wire is galvanized cast steel with a tensile strength of 82.6 tons per square inch for the smaller diameter and 90 to 100 tons per square inch for the larger diameter. The ropes were of the special patent locked construction of irregular shaped sections of wire, manufactured by Felten & Guilliaume at Muelheim-on-Rhine.

The Nuremberg company's cable construction is unusually novel. It consists of a group of parallel wire ropes arranged in two or more vertical rows and entirely separated from each other, their relative positions and distances apart being secured by steel castings of suitable form. The special claims made for this construction are that each rope can be got at readily for inspection and repairs, or can be removed and replaced by a new rope. The suspenders are hung by pins from the steel castings, which maintain the positions and distances of the parallel ropes.

Coming home to America we reach more familiar ground and need only mention a few examples of suspension cable construction. The earliest suspension bridges of Finlay and Templeman had chain cables. Perhaps the earliest wire rope cable bridge in America was that built across the Schuykill River in 1806, with a span of 408 ft. The real originator of wire rope suspension cables in America was, however, Charles Ellet, whose greatest work was the Wheeling Bridge of 1,010 ft. span, built in 1848. The next notable suspension bridge was that of Edward W. Serrell across the Niagara River at Lewiston, N. Y., built in 1851, which had a span of 1,042 ft. and cables of parallel wrought-iron wires. Roebling's railway bridge across the same stream, built four years later, had, however, wire rope cables. In fact, it was not until the Cincinnati Bridge was built in 1867, with its span of 1,057 ft., that parallel wire cables were again used. Following the Cincinnati Bridge came the Brooklyn Bridge, with a parallel wire cable span of 1,595½ ft., and the Williamsburg Bridge, with a span of 1,600 ft. and similarly constructed cables.

Of the five plans for suspension bridges of upwards of 3,000 ft. span across the North River at New York, each the work of a different set of engineers, all but two were designed with parallel steel wire cables. The two exceptions were the designs of Mr. Geo. S. Morison and Mr. Gustav Lindenthal. Mr. Morison proposed to use a special form of wire rope cable and Mr. Lindenthal proposed a cable made up of several sections or links of parallel wire cable coupled one to the other. The records and descriptions of both of these designs are readily available and they need not be described further here.

The conclusions to be drawn from this brief record of suspension bridge cable construction are: First, that Mr. Lindenthal by no means stands alone in departing from the familiar construction of parallel wires, and, second, that no other engineer has been so bold as to return to the old chain cable design for a suspension span at all approaching in length that of the new Manhattan Bridge. In a future issue we may have something more specific to say respecting the problems involved in constructing a chain cable of such dimensions.

LETTERS TO THE EDITOR.

Fence-Wire Telephone Lines in Colorado.

Sir: Among the many interesting engineering contrivances I have found in Colorado, I take the liberty of communicating to you seemingly the most commonplace but in my mind the most ingenious and useful of them all, viz.: that of using the top wire of the fences as a metallic telephonic circuit; small poles are used to carry a connecting wire over gateways and across the public roads when necessary.

No insulation is found essential on the fence posts aside from carefully separating the wire from the others and only a few days in the year is the communication interrupted by the weather.

More than 100 homes situated in Clear Creek Valley, between Denver and the foothills, are successfully connected in this manner. Yours,

W. P. Bullock, C. E.

2659 Stout St., Denver, Colo., Nov. 17, 1902.

(Fence-wire "farmers'" telephone lines exist in many parts of the country. The Central States especially have many such lines. In fact, the demand which the existence of such lines indicates was the direct cause of the formation of many of the independent telephone companies flourishing in that part of the country.—Ed.)

Determining the Size of Hoisting Plants: Correction—Tests of Wires for Wire Rope.

Sir: In my article on "Determining the Size of Hoisting Plants," reprinted in Engineering News of Oct. 16, 1902, there is an error which has been corrected for final publication in the Transactions of the A. I. M. E., namely, on p. 318, second column, the sentence beginning on the fifth line of the paragraph commencing Mr. William Hewitt should read:

"The 'maximum safe load' is taken as ⅓ the ultimate strength; this is well below the elastic limit of the wire."

While this sentence appears in connection with discussion of wire ropes from the Trenton Iron Co.'s treatise, it is but fair to Mr. Hewitt to say that he did not make the statement as originally printed in the last clause.

In this connection the result of a series of 2,310 tests on rope wire made at the Washington Navy Yard in 1876-1879 will be of interest, as showing the limit of elasticity found in the wires of the different grades.

Tests on Wire Made at Washington Navy Yard, 1876-1879.

Grade of wire.	No. of tests.	Diameter of wire, ins.	Aver. tensile strength, lbs. per sq. in.	Aver. limit of elasticity, lbs. per sq. in.	Ratio bet. elasticity limit and tensile strength, %.
Steel	270	.0255 to .192	139,980	72,688	51.93
Galvanized steel	210	.023 to .160	138,275	76,520	55.34
Galvanized tempered crucible steel	60	.067 to .173	197,793	40,724	20.59
Tempered steel	210	.025 to .163	209,217	115,806	55.35
Galvanized annealed steel	100	.027 to .1305	73,100	44,909	61.44
Annealed steel	240	.0245 to .1615	78,129	42,680	54.63
Iron, Best, B. B. charcoal and Norway	650	.028 to .165	91,387	59,529	65.14
Same, galvanized iron	190	.064 to .169	79,179	48,674	61.35
Annealed iron	160	.0265 to .1295	59,323	25,947	43.74
Galvanized annealed iron	160	.027 to .1315	58,159	25,171	43.28

Yours very truly, Edward B. Durham.

Trenton, N. J., Nov 18, 1902.

Concerning Concrete-Steel Construction.

Sir: I note the editorial in your issue of Nov. 6, relative to proper placing of concrete in cases where it is heavily reinforced with steel bars.

In the first place, I should explain that the concrete sections referred to in my article on "Columns for Buildings" as so heavily reinforced were the compression halves of girders and cantilever brackets, and not columns. But the engineers responsible for the designs assured me that they propose to carry reinforcement against compression to the same point in the case of the lower columns of heavy buildings, whenever they have such work to do.

Good concrete is just as important in the case of reinforcing against tension, in order that slipping may not occur. The concern referred to recently put in some heavily reinforced footings in Washington; I was interested in the very question you raise, and went to see the work executed. Thy used rather small gravel for the aggregate, made the concrete rather wet, and rammed it in the narrow spaces between the reinforcing bars with rammers consisting of iron bars with a piece of flat iron welded on at the end so as to make a ramming head about ¾-in. thick and possibly 4 ins. wide. It was tedious and expensive, but with the wet concrete, made of small gravel, the work went on quite expeditiously and with evident economy.

Forms will be the most expensive item in the cost of placing reinforced concrete; the close juxtaposition of the reinforcing bars will, on close acquaintance, prove to be, I think, a minor matter. Moreover, not a large percentage of cases will occur where the bars will have to be so numerous and so close together. The fact that a comparatively large number of such cases have occurred and been successfully handled was referred to as strong evidence in support of the great stiffening effect of concrete, not as an example of the most desirable sort of design in ordinary cases.

So far as expense is concerned, I should say that, in most cases, the concrete in reinforced constructions will cost at least $10 per cu. yd. placed, and still leave a good margin below the cost of steel beams and any form of fireproof floor construction in common use; $10 per cu. yd. would allow a good deal of labor to be expended on both forms and careful ramming.

Very truly yours, John Stephen Sewell,

Captain, Corps of Engineers, U. S. A.

735 N. Capitol St., Washington, D. C., Nov. 13, 1902.

A "Treatise" on Earth Roads.

Sir: I have just learned that Mr. A. J. Sager, of Climax, Mich., has published a pamphlet entitled "Earth Roads," of which 60% was taken from an article by the undersigned published as Bulletin No. 65 of the Illinois Agricultural Experiment Station under the title, "Construction and Care of Earth Roads," and which you republished (with proper credit) in Engineering News for April 18, 1901. Mr. Sager not only gives no credit and makes no acknowledgments, but labels his pamphlet "Copyrighted by A. J. Sager, 1902."

When Mr. Sager's attention was called to the above facts he admitted the use of the article, but offered no excuse or explanation further than to say that he thought I had no further use for it, and to call my attention to the fact that his article had been republished in various newspapers and in several widely distributed pamphlets, some of these articles being almost wholly my matter.

I feel compelled to enter a public protest against this use of my article, since I am shortly to publish a book on roads and pavements, which contains the matter used by Mr. Sager, and I do not want to be accused of having appropriated matter written by Mr. Sager.

Ira O. Baker.

University of Illinois, Champaign, Nov. 17, 1902.

(We have compared the Sager pamphlet with the Bulletin written by Prof Baker. The title page of the pamphlet reads: "Earth Roads: A Treatise on the Country Road, by A. J. Sager," and he inserts his portrait as a frontispiece, after which he makes his treatise by copying verbatim nearly two-thirds of the matter from Prof. Baker's work. We understand that several thousands of these pamphlets have been distributed free at State Fairs and elsewhere. Curiosity is naturally aroused as to why a private individual should undertake free distribution of "good roads" literature on such a scale; but a probable explanation is found when the "author" of the treatise lugs in a recommendation of a particular make of road machine.

The only redeeming feature of the case is that Prof. Baker's excellent ideas on highway construction have been brought before a wider circle of readers.—Ed.)

Unaccounted-for Water in Massachusetts Cities and Towns.

Sir: I note with great interest what is said in the article on "The Consumption of Water in Cities and Towns in Massachusetts," in your issue of Nov. 20, regarding the waste of water, and the percentage that the

water pumped but unmetered bears to the total, even in cities where practically all of the services are metered. To a person more familiar with electric and gas statistics than with water plants the figures appear astounding, and it would be very interesting to know if there is any reason why there should be so much more loss with water than with gas or electricity. It cannot be the pressure, otherwise the English high-pressure distribution plants in London, Manchester, etc., that work at 750 and 1,500 lbs. per sq. in., would find it impossible to exist. Neither can it be the fact that the water plants are mostly municipal plants, though if I remember rightly the Philadelphia gas leakage approached to the figures shown for water plants, while the Massachusetts municipal gas plants have an average leakage that is exceeded by only about one private plant out of five and is increasing.

The average gas loss appears to be about 10%; the average electric loss a little less; while the water loss appears to be over 50%. Is there any reason? R. S. H.

Boston, Nov. 21, 1902.

(It is rare, indeed, for a water-works plant to measure anything like so large a percentage of its output, as do practically all gas works. All the works included in our article pump all the water supplied, and it is becoming increasingly evident that much of the registered pumpage never reaches the mains, due to no allowance, or inadequate allowance for slippage. Even making allowances for the differences in pressure in English hydraulic service lines, and in Massachusetts water-works, probably the pipes of the latter are more prone to leak than those of the former. It does not seem fair to compare the average gas loss in Massachusetts with the water loss in a few places, and there are only a few where even 90% of the taps are metered. Finally, there is altogether too much estimating required to arrive at unaccounted-for water, except in the very few cases where all taps are metered, to make accurate figures possible.—Ed.)

A Versified Explosion.

Sir: Herewith I enclose to you a clipping from the "Lynn Item" of Nov. 19, 1902, and regret that I do not know who is the author, as it appears to me to compare favorably with the famous Canadian dialect poems of Dr. Drummond. Engineering humor is rare, and I do not remember ever seeing the Italian patois put into rhyme before. Swampscott is putting in an extensive system of sewerage and the great blast which was the inspiration of the poem and the destruction of stone crusher, boiler, window glass and nerves occurred last week.

Yours very truly, H. J. C.

Boston, Mass., Nov. 20, 1902.

(We print below the verses accompanying the letter. Their author is said to be one of the contractor's foremen, and we regret that his name is unknown, so that we cannot give him due credit. He has certainly "held the mirror up to Nature" remarkably well.—Ed.)

MEEST' McDONOUGH'S BLAS'.

Da nicea boss is Meest' McDon',
Da contaractor man,
He lika for to get da job
Mos' everywhere he can.

He gooda man for do da hust',
He finea man for rush;
He builda sewer, collect da cash
An' run da stona crush.

Da onea time, I 'member me
'Bout tree mont' ago—
(Mebbe I guess it only two;
P'raps I donta know).

Da bigga boss he say to me,
"I tella you, Simone,
I want you shoot da bigga blas'
For busta fine da stone."

"All right," I tell him; "Meest' McDon'"
I fixa me all right."
He get da bugga and da hoss
An' driva outa sight.

I get da dynamita steek,
Fourteen, or mebbe nine,
I get da prime', da batt'ry,
I fix da wire line.

An' den I yella, "Fire! Blas'!"
An' get behin' da tree.
Da everybody else, dey hide,
I push da batt'ry-me.

Da rock, he'll shoot up in da air,
He'll mos' go outa sight;
Da odder rock, he'll hop aroun'—
I busta fine all right.

Some piece he hit da stona crush',
Some piece da boiler fell;
I don'ta stop see where he land—
I runna lika—well!

Da stona crush' smash all to dev',
I speaka you da trut'—
You no could find a piece as big
For picka all your toot'.

I tella you, I no forget
So long a time I las'
Dat time I push da batt'ry
For Meest' McDonough's blas'.

A Unit of Quantity of Electricity for Use in Electrochemical Work.

Sir: In your issue of Nov. 13th, you published a communication from me in relation to a proposed unit of quantity of electricity, for use in electrochemical calculations. In this letter it was pointed out that a "kilocrith col," or 100 international amperes for one sidereal day, liberates, in the electrolysis of water, 1.00071 cubic meters of hydrogen, at the mean pressure of the atmosphere at sea level. I mentioned that the sidereal day measures the true revolution of the earth on its axis, and that this coincidence was so close as to naturally raise the question as to whether the agreement is absolute or not.

Since that communication was written, Prof. Reginald A. Fessenden, in a communication to the "Electrical World and Engineer," has pointed out that the above coincidence cannot be a perfect physical agreement for the reason that the atmospheric pressure is temporary, varying in its magnitude at different periods in the world's history. He suggests that during the Carboniferous Age the atmospheric pressure was probably much greater than now, and consequently the relation to which I have called attention must be merely coincidence. The pressure of the atmosphere would have to be constant through all time in order that this agreement should be fundamental, and therefore I have to acknowledge that the point raised by Professor Fessenden was well taken.

The coincidence, however, is a fortunate one, as it enables the creation of a set of units of electrical quantity that co-ordinate with the avoirdupois pound and with the metric measure of volume, and that can be defined in terms of international amperes and the mean solar day of time, closely enough for practical purposes. This may be appreciated from the following table. While the table refers to the weights of hydrogen that would be liberated, the units of weight reach to all other elements. When hydrogen is taken as unity in the table of atomic weights the atomic weight, divided by the valency which an element manifests in electrolysis, will give, in terms of any of the following units, the weight of such element that would be liberated by the respective electric quantities, as follows:

		Ampere days.				%
Pound col	=	500.	and liberates		1 pound	(−0.59)
Grain col	=	0.072	"	"	1 grain	(+0.2)
Kilogram col	=	1,110.	"	"	1 kilogram	(+0.1)
Gram col	=	1.11	"	"	1 gram	(+01)
Kilocrith col	=	100.	"	"	1 kilocrith	(+0.34)
Crith col	=	.1	"	"	1 crith	(+0.34)

A col unit quantity of electricity is a quantity which co-ordinates with any particular unit of weight, the name of that unit of weight being used as a prefix to designate such co-ordination. To define the metric col units exactly, in their equivalence to ampere seconds, we may employ a number of mean solar seconds nearly equivalent to the day of time. In this case the numeral (ignoring the decimal point) which expresses the number of amperes that must flow for this time in order to equal a kilogram col, or a gram col, becomes naturally the same numeral that also expresses the specific gravity of water with hydrogen as the unit of specific gravity. This is shown in the following table:

		Amperes.		Seconds.		
Kilogram col	=	1,112.7	for	86,103	to free	1 kilogram.
Gram col	=	1.1127	"	86,103	" "	1 gram.
Kilocrith col	=	100.	"	86,103	" "	1 kilocrith.
Crith col	=	.1	"	86,103	" "	1 crith.

It may be added that a crith weight is equal to the weight of a liter, or cubic decimenter, of hydrogen, .089873 grams, and if we measure in criths the weight of hydrogen that a kilogram col liberates, the weight is found to 11,127 criths. This figure also expresses exactly the specific gravity of water with hydrogen as the unit of specific gravity.

Ordinarily, in calculations made to determine the weight of any element that a given current will free in a given time, we multiply the electrochemical equivalent of that element for one coulomb, by a figure that closely approximates 96,000. But this method necessitates referring to a table of electrochemical equivalents, and if we are not dealing in grams, we must calculate from the gram equivalents to the respective unit of weight employed. It will be observed that the units above suggested can be easily remembered, and when the valency and atomic weight of an element are known, the calculation of the amount of an element that will be liberated by any given current in any given time can be performed mentally and with great rapidity.

Alfred H. Cowles.

361 The Arcade, Cleveland, O., Nov. 15, 1902.

THE DEVELOPMENT OF MODERN ORDNANCE AND ARMOR IN THE UNITED STATES.*

By Rear-Admiral Charles O'Neil, U. S. N.†

The development and manufacture in the United States of modern ordnance afford a striking illustration of progress made in those interesting branches of science, and it is the purpose of this paper to review briefly the most prominent facts in connection therewith.

*Abstract of a paper read at the tenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, Nov. 20 and 21, 1902.

†Chief of the Bureau of Ordnance, U. S. N., Washington, D. C.

At the present time, when anything pertaining to ships of war, their armament, and military science in general, excites so much popular interest, it is difficult to understand the apparent indifference that prevailed in this country with respect to them for a number of years following the Civil War of 1861-'65, notwithstanding the fact that the serious attention of all other maritime nations of importance was given to efforts to improve them, and that marked improvements were in fact being made abroad.

This was probably due in part to the fact that the country had had enough of war, and was more interested in recovering from its dire effects and readjusting itself to new conditions than in the consideration of naval or military matters except so far as pertained to a reduction of both branches of the public service. Another reason may have been the very uncertain status of the arts so far as ships of war and more efficient ordnance were concerned, as no well established line of development was in sight in the early sixties, either as regards material or method of construction for ships or guns, except that the day of wooden ships and cast-iron guns had gone by.

It should be said, however, in justice to the several chiefs of ordnance of the navy, that from year to year they clearly set forth in their annual reports to the Secretary of the Navy the wretched and inefficient character of our naval ordnance as compared with the standards of the day, and recommended that steps be taken to re-arm the entire navy with modern rifled cannon, calling attention to the progress being made abroad and to our inferiority in such matters. This was notably the case from 1873 to 1880, when Commodore Wm. N. Jeffers was chief of the bureau of ordnance.

ORDNANCE.

As is generally known, our naval ordnance for some years prior to and during the Civil War consisted chiefly of cast-iron, muzzle-loading, smooth-bore guns of the Dahlgren type, designed in 1850-'51 and introduced into the navy soon thereafter. During the Civil War a considerable number of Parrott rifles were introduced both into the army and navy. These guns had cast-iron bodies, reinforced over the powder chamber by a wrought-iron hoop, which was shrunk on.

CAST-IRON SMOOTH-BORE GUNS OF THE CIVIL WAR.—At the commencement of the year 1861 the ordnance of the navy consisted of 2,830 smooth-bore guns, 2,474 of which were of old type and 356 being of the Dahlgren type. In addition there were 136 12 and 24-pounder boat guns. A total of 2,966 guns. There were, in addition to a number of howitzers, 555 guns mounted on ships of the navy in commission, as follows: In frigates, 100; in sloops, 232; in storeships, 7; in screw frigates, 12; in first-class steam sloops, 90; in side-wheel steamers, 40; in second-lass steam sloops, 45; in third-class screw steamers, 28; in steam tenders, 1.

The remaining guns were either on board vessels in ordinary, on receiving ships, or parked in the several navy yards on the Atlantic coast.

On Nov. 1, 1863, the total number of naval guns was 5,777. Of this number, 4,746 were smooth-bores (1,197 being of the Dahlgren type), 691 were Parrott rifles, and 338 were rifled howitzers. This number was subsequently increased, and a number of 60-pdr. Parrott rifles were also manufactured.

A considerable number of Parrott rifles were put in service and were favorably regarded until several of them burst, from one cause or another, the records of the Navy Department showing that two 150-pdrs., 15 100-pdrs., one 80-pdr., three 30-pdrs., and three 20-pdrs. burst during proof or in service; and it is stated that several Parrott rifle guns burst at Morris Island in 1863 during General Gilmore's operations before Charleston, S. C.

A board of officers was convened to investigate the cause of the bursting of the guns referred to, and the conclusion arrived at was that it was due to the premature bursting of loaded shells in the bores of the guns, and that these explosions were due to the powder charge of the shells being ignited by friction caused by the rotary motion of the shells.

In the year 1877, a 100-pdr. Parrott was converted into an 80-pdr. breech-loader by cutting off the breech end and inserting a steel liner, the latter being screwed into the body of the gun after the latter had been expanded by heating, the old band over the powder chamber being replaced by a larger one. Ten guns in all of this class were converted into breech-loaders.

In the year 1878 and following, 28 60-pdr. Parrott rifles were converted into breech-loading guns by cutting off the face of the breech and inserting a steel-lining tube about 4 ft. long, which was screwed into the cast-iron body of the guns. These guns answered their purpose fairly well, and remained in service a number of years, though some of them are known to have burst, notably two on board the practice vessel "Standish," attached to the Naval Academy.

The cast-iron smooth-bores in general use at the time of the Civil War were those of 15, 11 and 9 ins. in caliber. The former were carried exclusively as turret guns of monitors; the 11-in. were used as pivot guns and the 9-in.

for broadside batteries of all the more important vessels. As these guns are practically unknown to the present generation and have nearly all been sold as old iron, except such as have been donated to soldiers' manument associations, Grand Army Posts, and municipalities, it may not be uninteresting to refer to them in some detail by way of comparison with the ordance of to-day.

The 15-in. gun weighed 42,000 lbs. (18.7 tons); its length over all was 181 ins. (15 ft. 1 in.); its maximum diameter was 48 ins.; its ordinary charge consisted of 35 lbs. of black cannon powder and a spherical shell weighing 350 lbs. Under extraordinary conditions such guns might

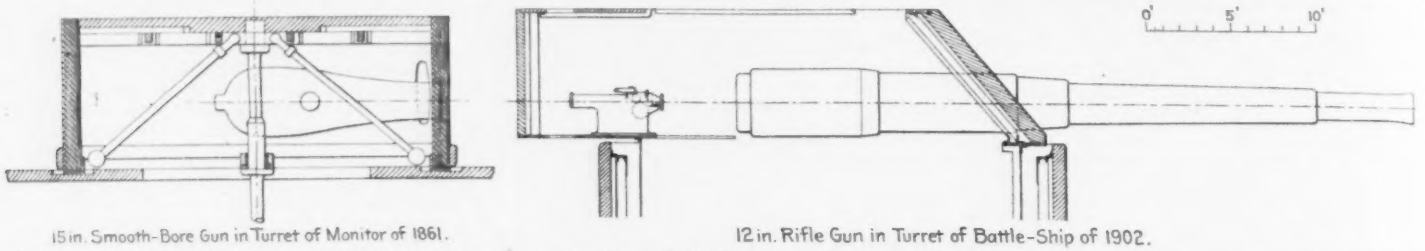


FIG. 1. COMPARISON OF 15-IN. SMOOTH-BORE GUN OF 1861, AND MODERN 12-IN. RIFLE OF 1902, AS MOUNTED IN THE "MONITOR" AND IN A MODERN BATTLESHIP.

under the regulations be fired 20 rounds "at ironclads at close quarters," using 100 lbs. of hexagonal or cubical powder and solid shot weighing 450 lbs. Under the latter conditions a muzzle velocity of 1,600 ft.-secs. was attainable, with a corresponding muzzle energy of 7,997 ft.-tons. Such being the most powerful guns afloat in the navy in 1861, it will be interesting to compare its muzzle energy of 7,997 ft.-tons with that of the most powerful guns afloat to-day, namely, the latest type of 12-in. rifle, whose muzzle energy is 46,246 ft.-tons. The old 15-in. smooth-bore, therefore, when fired with 100 lbs. of powder, would develop 427 ft.-tons energy per ton of gun as against 872 ft.-tons energy per ton of gun in the case of the 12-in. rifle, which weighs 53 tons.

The 11-in. smooth-bore gun weighed 16,000 lbs.; its length was 13 ft. 3.7 ins. (about one-half that of a modern 6-in. gun); its charge was 27 lbs. of black cannon powder and a spherical shell weighing 166 lbs. Under these conditions its muzzle velocity was 1,062 ft.-secs., with a corresponding muzzle energy of 1,300 ft.-tons.

The 9-in. smooth-bore gun weighed 9,000 lbs.; its length was 11 ft.; its charge was 10 lbs. of black cannon powder and a spherical shell weighing 70 lbs. Under these conditions its muzzle velocity was 1,320 ft.-secs., with a corresponding muzzle energy of 847 ft.-tons.

The old 9-in. gun with its 847 ft.-tons muzzle energy was the favorite broadside gun of our finest frigates during the Civil War. To-day the 6-in., 50-caliber rifle, with a muzzle energy of 5,836 ft-tons, is the favorite broadside gun of our battleships and cruisers.

The muzzle energy of the latest type of 12-in. rifled gun is 54 times as great as that of the old 9-in. smoooth-bore; so that one round of a modern 12-in. gun develops as much energy as would one round from each gun of a 54-gun frigate armed with 9-in. smooth-bore guns.

In the year 1876 and following, 51 11-in. smooth-bore guns were converted into muzzle-loading rifles of 8-in. caliber by the insertion of a wrought-iron coiled and welded tube or liner, the body of the gun being bored out to a diameter of 12 ins. to receive the liner, which was 2 ins. thick. This increased the weight of the gun from 16,000 to 18,000 lbs. The charge for the converted guns consisted of 35 lbs. of black hexagonal powder and an elongated cast-iron projectile weighing 180 lbs. Under these conditions its muzzle velocity was 1,450 ft.-secs., with a corresponding muzzle energy of 2,627 ft.-tons, an increase of muzzle velocity of 388 ft.-secs., and of muzzle energy of 1,327 ft.-tons, due to such conversion.

These were considered the most effective guns in the United States Navy before the introduction of the high-power, built-up steel guns in the year 1884.

Prior to the introduction of modern ordnance in the United States Navy, great progress had been made by other countries in the manufacture and development of guns built up of steel forgings.

From the year 1865 to 1883 the navy was not only at a standstill, but dwindled into insignificance as its wooden ships were dropped one after another from the navy list as they got beyond repair, until we had but a shadow of a navy remaining, and our few obsolete ships and antiquated guns excited the ridicule of foreign powers, and were a source of deep mortification to the officers of the navy. In the annual report of the Secretary of the Navy (Hon. Wm. H. Hunt) for 1881, he remarks:

> The condition of the navy demands the prompt and earnest attention of Congress. Unless some action be had in its behalf it must soon dwindle into insignificance.

In November, 1882, Hon. Wm. E. Chandler, then Secretary of the Navy, in his annual report, says:

> Having no effective guns, it is the duty of the government to begin their manufacture immediately. The country is not now capable of making the steel forgings necessary for heavy rifled cannon; they must therefore be procured from abroad or inducements offered to steel manufacturers to engage in their production.

Such was the state of affairs as regards modern ordnance in the navy in 1882.

BUILT-UP STEEL GUNS.—As early, however, as 1878, the chief of the bureau of ordnance of the Navy Department (Commodore Jeffers) designed a 6-in., built-up, steel, breech-loading rifled gun, and made every effort to obtain the forgings for its manufacture in the United States, but after repeated failures was obliged to purchase the jacket for this gun in England, although the tube was successfully made in the United States. This gun, the first improved breech-loading rifle made in the United States, was finished and put on the naval proving ground at Annapolis in 1882, where it performed most useful work in the development of brown prismatic powder, the manufacture of which was, about that time, through the efforts of the bureau of ordnance of the Navy Department, introduced into the United States. This first 6-in. gun, although fully up to date at the time it was designed, would to-day be considered as very low-powered, having a muzzle velocity with a 100-lb. projectile of only about 1,800 ft.-secs.

The Navy Department is properly entitled to the entire credit for developing the manufacture of modern breech-loading, all-steel, built-up rifles in the United States. In 1883, Congress authorized the construction of four modern vessels, namely, the cruisers "Atlanta," "Boston," and "Chicago," and the despatch boat "Dolphin," and also appropriated money for the completion of five double-turreted monitors then in an unfinished state, and it became necessary to supply them with modern guns, and funds thus being available, the bureau of ordnance of the Navy Department began the installation of a plant for the manufacture of guns at the Washington Navy Yard, which has since developed into one of the largest and best equipped ordnance factories in the world. At the same time plans were prepared for high-power, steel, breech-loading cannon of all calibers, designed to give a muzzle velocity of 2,000 ft.-secs., that being the highest standard of the day.

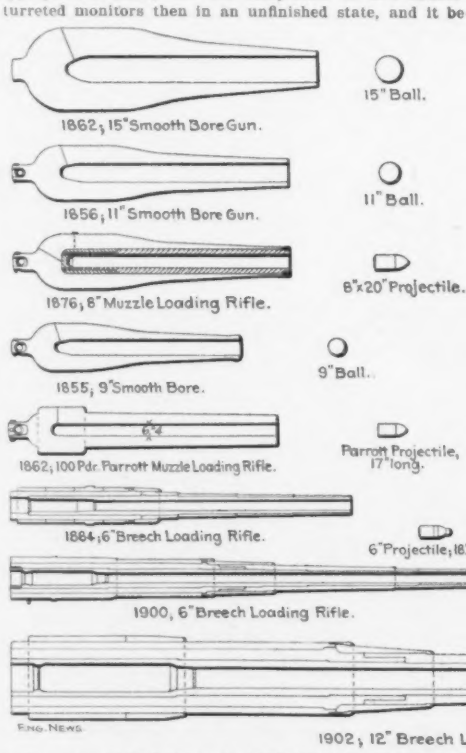


FIG. 2. DIAGRAM ILLUSTRATING DEVELOPMENT OF GUNS AND PROJECTILES IN U. S. NAVY FROM 1862 TO 1902.

Type of gun.	Weight of gun.	Length of gun.	Charge of gun.	Weight of shell.	Initial velocity, per second.	Muzzle energy, ft.-tons.
15-in. smooth bore	18.7 tons.	15 ft. 7.0 ins.	35 lbs.	350 lbs.	1,600 ft.	7,997
11-in. smooth bore	7.14 "	13 " 3.7 "	27 "	166 "	1,062 "	1,300
8-in. muzzle-loading rifle	7.76 "	13 " 3.7 "	35 "	180 "	1,430 "	2,627
9-in. smooth bore	4.0 "	11 " 0.0 "	10 "	70 "	1,320 "	847
100-pdr. Parrott	4.35 "	12 " 1.4 "	10 "	100 "	1,080 "	810
6-in. breech-loading rifle	4.74 "	16 " 4.0 "	36 "	100 "	2,000 "	2,773
6-in. " " "	8.46 "	25 " 0.0 "	40 "	100 "	2,900 "	5,838
12-in. " " "	53.4 "	45 " 0.0 "	360 "	850 "	2,800 "	46,246

The establishments of the great works of the Bethlehem Iron Co., at South Bethlehem, Pa., and the further enlargement of the works of the Midvale Steel Co., which was the pioneer in the manufacture of gun gorgings in the United States, made it clear that no other gun forgings would have to be purchased abroad, and with the exceptions noted, all the guns with which the United States Navy is armed are constructed of domestic material and all without exception were made in the United States, and with some modifications upon the same plans originally adopted by the bureau of ordnance of the Navy Department.

Many improvements in ordnance have, of course, been made, but the general character of the guns, so far as their construction is concerned, is practically that decided upon in 1878, and the fact that after hundreds of guns of all calibers up to and including 13-in. have been built and placed on naval vessels with no cases of failure in war or in peace, with the exception that the muzzles of one 4-in. and one 5-in. gun were broken off at target practice, affords satisfactory evidence of the wisdom of the Navy Department in its original adoption of a type of gun and in its adherence thereto.

In June, 1887, the first large order for gun forgings and armor was placed by Hon. Wm. C. Whitney, then Secretary of the Navy, with the Bethlehem Iron Co. (now the Bethlehem Steel Co.), which commenced deliveries of forgings for 6-in. guns in 1888. Since 1883 some 1,400 sets of gun forgings for main battery guns alone have been manufactured in the United States for the navy.

The first modern 6-in. gun for the navy, completed in 1884, weighed 4.8 tons; was 15 ft. in length (that is, 30

had the courage of his convictions and the executive ability to carry them out. He was probably the most scientific and highly educated ordnance officer the navy has ever had, and thoroughly understood the science in all its branches.

As there were no establishments in the United States then (1883) equipped for the manufacture of gun forgings, orders were placed in England with Sir Joseph Whitworth & Co. and Chas. Cammel & Co. for three sets of forgings for 10-in. and for eight sets for 8-in. guns. The Midvale Steel Co., of Philadelphia, undertook the manufacture of the smaller gun forgings, and supplied 59 sets for 6-in. guns before any other establishment in this country was in condition to supply any; that is, between the years 1883 and 1888. The orders for the manufacture of the guns for these first vessels of the new navy were divided between the Washington Navy Yard, the West Point Foundry, and the South Boston Iron Works.

calibers), and had a chamber capacity of 1,408 cu. ins.; the charge was 45 to 50 lbs. of brown or "cocoa" powder, that being the kind then in use; its projectile weighed 100 lbs. The gun was designed for a maximum chamber pressure of 15 tons per sq. in.; its muzzle velocity was 2,600 ft.-secs., and its corresponding muzzle energy was 2,773 ft.-tons; its power of perforation of wrought iron at the muzzle being 11.19 ins.

Three separate movements were necessary to open or close the breech of this gun, and it was fitted for percussion firing only. Its rate of fire was one round in one minute, or thereabouts. The gas was checked at the breech end by a plastic pad between two steel disks in front of the breech plug. It was mounted on a gravity-return mount requiring several men to operate, its recoil being taken up by a hydraulic cylinder under the front end of its mount. Twenty-one guns were made of this type, after which improvements were made in the breech mechanism whereby but two movements were required to open the breech, and the mounts were considerably improved, though the principal features of the original ones were retained.

There were made 123 6-in. guns, 30 calibers in length, six of 35 calibers, and 68 of 42 calibers. The latter were essentially of the rapid-firing type, having quick-working breech mechanisms which opened with one movement, and the powder charge being contained in a brass-cartridge case, there was no sticking of the breech plug, nor fouling of the bore. These guns were fitted for electric and percussion firing, were mounted on pedestal mounts which were capable of being operated by one man, and were supplied with telescopic sights. The guns recoiled in the line of fire and were returned to the firing position by means of spiral springs in the recoil cylinders, which were compressed when the guns recoiled. The 42-caliber gun was 21 ft. 3 ins. in length and weighed six tons. With brown powder and a 100-lb. projectile its muzzle velocity was 2,150 ft.-secs. and its muzzle energy was 3,204 ft.-tons. With smokeless powder, however, the muzzle velocity was raised to 2,550 ft.-secs. and the muzzle energy to 4,507 ft.-tons, an increase in muzzle energy of 40%, and of 63% over that of the 30-caliber gun using brown powder.

From the year 1885 to 1900 there was no very marked advance made in our naval guns, except as above stated, and in the details of their mechanisms; but the introduction of slow-burning smokeless powder materially increased their efficiency, as illustrated in the case of the 6-in. gun. In the year 1900, however, new designs were made of United States naval guns of all calibers, whereby they were made considerably longer, heavier and stronger, and with enlarged powder chambers, in consequence of which their energy has been increased in a marked degree.

The latest type of 6-in. gun is 25 ft., or 50 calibers in length, and weigh 8.2 tons. It has a possible rate of fire of nine rounds a minute on the proving ground and a practical rate of fire of five or six rounds on board ship for a short period. The muzzle velocity of the new gun is 2,900 ft.-secs., and its muzzle energy is 5,836 ft.-tons, an increase in muzzle energy over the 30-caliber gun using brown powder of 110%. The chamber capacity of the 50-caliber gun is 245 cu. ins. as against 143 in the 30-caliber gun, and the allowed chamber pressure in the new gun is 17 tons per sq. in. as against 15 tons in the earlier gun. A new 6-in., 50-caliber gun is now being made which is expected to give a muzzle velocity to a 100-lb. projectile of 3,400 ft.-secs.

As an indication of the comparative power of the various types of 6-in. guns, their ability to perforate wrought iron at the muzzle will suffice. The 30-caliber gun at 2,000 f.-s. m. v. will perforate 11.19 ins.; the 40-caliber at 2,550 f.-s. m. v., 15.84 ins.; the 50-caliber gun at 2,900 f.-s. m. v., 19.04 ins., and the 50-caliber gun at 3,400 f.-s. m. v., 23.9 ins.

The 6-in. being a gun of medium caliber, and being the intermediate caliber on a number of our most important vessels, is specially referred to; but the 3, 4, 5, 7 and 8-in. guns were all designed and developed on the same principle and are equally efficient. The later guns are perfectly balanced in their slides when loaded, and are mounted on carriages having ball-bearings or frictionless rollers, and can be trained in the vertical and horizontal planes with very great facility.

In the later 5 and 6-in. guns the brass cartridge case has been abandoned, as smokeless powder does not foul the chamber of the gun, and the case is not therefore necessary.

The heaviest guns now in use or that have been used in our navy are those of 13 ins. in caliber, weighing 60½ tons. Such guns are carried by eight of our battleships, each vessel carrying four. The latest vessels to be equipped with such guns are the "Alabama," "Illinois," and "Wisconsin."

The later battleships, beginning with the new "Maine" and class and the four harbor-defense monitors now about completed, carry guns of 12-in. caliber, and a comparison between them and the earlier guns of the same caliber will illustrate the development which has taken place.

The Mark I. and Mark II. 12-in. guns, of which there are but 12 in service, were manufactured between the years 1892 and 1897. Such guns weigh 45.2 tons and are 36.8 ft. in length, their greatest diameter being 45 ins. The powder chamber is 6 ft. 10 ins. in length, and its maximum diameter is 14.5 ins., and its capacity is 12,043 cu. ins. They were designed for a maximum chamber pressure of 15 tons per sq. in. With a charge of 425 lbs. of brown powder, these guns give a muzzle velocity to an 850-lb. projectile of 2,100 ft.-secs. and a muzzle energy of 25,985 ft.-tons, having the power to perforate 33.74 ins. of wrought iron at the muzzle. The use of smokeless powder in these guns give them a muzzle velocity of 2,300 ft.-secs. with a corresponding muzzle energy of 51,170 ft.-tons, with the power to perforate 38.43 ins. of wrought iron.

The Mark III. 12-in. gun, designed in the year 1900, 48 of which are assigned to vessels built and building, weighs 52 tons; is 41.6 ft. in length, its greatest diameter being 48½ ins.; the powder chamber is 7 ft. 4 ins. in length, its greatest diameter being 16½ ins., and its capacity 17,360 cu. ins., or 44% greater than that of the Mark I. and II. guns. The gun is designed for a maximum chamber pressure of 17 tons per sq. in.

With a charge of about 360 lbs. of smokeless powder, and a projectile weighing 850 lbs., these guns develop a muzzle velocity of 2,800 ft.-secs., and a corresponding muzzle energy of 46,246 ft.-tons, which is 77% greater than Mark I. and II. guns using brown powder, and 48% greater than the same guns using smokeless powder. The Mark III. gun has the power to perforate 50.9 ins. of wrought iron at the muzzle.

Using capped projectiles, Mark I. and II. guns have the power to perforate 18 ins. of hard-faced armor at the muzzle, and the Mark III. gun has the power to perforate 23.5 ins. under like conditions.

Guns up to and including those of 7 ins. in caliber are now built essentially as rapid-firing guns, and the same principle could be applied to those of larger caliber, but the weight of the ammunition and the difficulty of handling it as quickly throws the large guns out of that category.

Among the guns recently designed is one of 7-in. caliber, 45 calibers in length, and weighing 13.3 tons. A type gun has been manufactured, designed to give a muzzle velocity of 2,900 ft.-secs., to a 165-lb. projectile within the limits of 17 tons per sq. in. chamber pressure, and having a muzzle energy of 9,646 ft.-tons, with power to perforate at the muzzle, with a capped projectile, 13.2 ins. of Krupp armor, and at 2,000 yds., 9.7 ins.

This gun has been proved to a velocity of 3,035 ft.-secs. with a maximum chamber pressure of only 16⅛ tons, a record which it is believed has not been equalled by any gun of similar class. This gun can readily be fired four times a minute, and similar guns will form the intermediary battery of battleships "Connecticut" and "Louisiana," each vessel carrying 12.

In view of the extraordinary development that has taken place with respect to ordnance, and the acknowledged endurance of built-up steel guns, it will be interesting to quote from the text-book on Gunnery, used at the Naval Academy in 1862, in which we read under the head of Objections to Breech-Loading Cannon, the following:

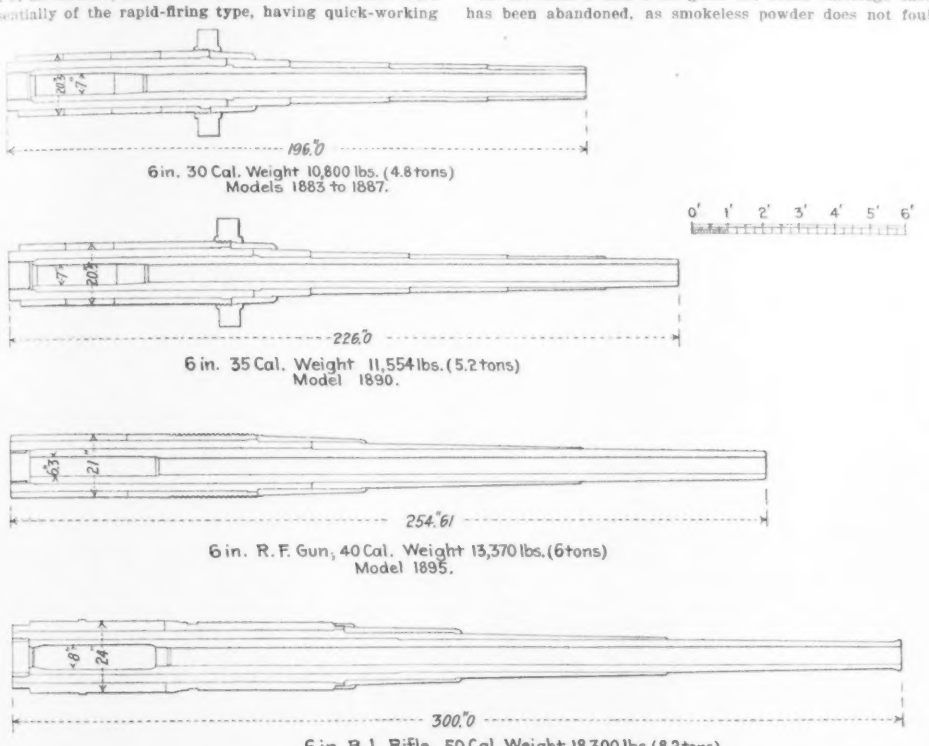
> In spite of the apparent success of the Armstrong & Whitworth gun, there are objections to breech-loading cannon which must be pointed out, and which go to prove that the endeavor to produce breech-loading cannon is an effort to obtain uncalled for and superfluous facility in gunnery. What superior property can it possess over the solid gun? It cannot be safety; for when we consider the very limited number of explosions by which the very best guns are destroyed, it can scarcely be possible for a gun composed of many parts to endure the intense vibrations to which large cannon are subjected.
>
> Vibration, if judiciously distributed, is the soul of endurance, but, if injudiciously distributed, is certain to result in the destruction of the cannon. In structures composed necessarily of many joints, obstructions to the waves of vibration must occur; the different parts do not expand and vibrate equally, a kind of revulsion is induced, part repels part, and destruction ensues as a natural consequence. Under no circumstances, therefore, can a breech-loading gun be as safe as a solid gun.
>
> The facility of loading and rapidity with which a breech-loading piece can be fired are spoken of as advantages of great importance, but these amount to nothing; for the gun, after every discharge must be relayed in order to obtain accuracy of air, and it is the pointing of a gun, and not the loading, that consumes time.

What was then referred to as "superfluous facility in gunnery" is now demanded and is easily accomplished, and instead of time being consumed in pointing time is now consumed in loading, as modern guns, properly mounted, are kept pointed all the time. There are in the navy to-day some built-up steel guns that has been fired upwards of 1,200 times without showing a sign of weakness, and the only effect of such firing is a slight erosion of the bore, due to the action of the powder gases.

While this country can lay no claim to the origin or early development of the steel built-up rifled guns, now universally adopted, it certainly has contributed in a large measure to their latest development, whereby the power of the gun, caliber for caliber, has been enormously increased and its details perfected.

The manufacture of gun steel in the United States has been brought to a high state of perfection, and forgings which used to require many months to supply are now turned out in as many weeks.

(Concluded next week.)



6 in. 30 Cal. Weight 10,800 lbs. (4.8 tons)
Models 1883 to 1887.

6 in. 35 Cal. Weight 11,554 lbs. (5.2 tons)
Model 1890.

6 in. R. F. Gun, 40 Cal. Weight 13,370 lbs. (6 tons)
Model 1895.

6 in. B. L. Rifle, 50 Cal. Weight 18,300 lbs. (8.2 tons)
Model 1898.

FIG. 3. DEVELOPMENT OF 6-IN CANNON IN U. S. NAVY FROM 1883 TO 1898.

A NEW SLIDE RULE has been patented recently by a Swiss inventor. It has a fixed scale, divided on steel, and over this, alongside its graduation, is an endless steel band running on rollers at the two ends. This band has its graduation continuous, so that as it is slid along there is always a full scale opposite the fixed scale. The fixed and movable scale are mounted in an aluminum case, covered by a plate of glass. The band is moved by a small knob projecting through a slot on the bottom of the case. The instrument as manufactured is 270 mm. long, 16 mm. wide, and 9 mm. thick, or 10.6 ins. by ⅝-in. by ⅜-in.; thus it is about the same size as the ordinary 10-in. wooden sliderule. It will be noticed from our description above that this rule has only one fixed and one movable scale, but these are of the full length of the rule; the continuous movable scale renders a double scale, like the upper scales of the ordinary rule, unnecessary for simple multiplication and division. The inventor of the rule is Mr. S. Masera, of Winterthur, Switzerland.

A COMMISSION OF ENGINEERS to study the two great problems of an additional water supply for Greater New York and the prevention of water waste has been appointed by Mayor Low, as follows: Prof. Wm. H. Burr, M. Am. Soc. C. E., of Columbia University, New York City; Mr. Rudolph Hering, M. Am. Soc. C. E., of 170 Broadway, New York City; and Mr. John R. Freeman, M. Am. Soc. C. E., of Providence, R. I. The scope of the inquiry is outlined as follows in a statement by Mayor Low announcing the appointment of the commission:

It is intended to ask these engineers to give all the necessary information with reference to every available watershed in sufficient detail to enable the city to know, as to each one, how much water can be had, how long it will take to get it, and how much it will cost per 100,000,000 gallons. With this information in hand, it ought to be possible for the city authorities to decide what is the best thing to do.

The commission will be instructed to give equal attention to the stoppage of waste. There is no disposition to undervalue the importance of such an inquiry as to waste, but it is clear that both branches of the inquiry should be carried on at the same time. Any enlargement of the water supply of New York upon a scale that will suffice for the growth of the city, even for a few years, will demand a large outlay of time, even after the plans have been developed and adopted. Any saving that can be made by the stoppage of waste will also take time and cost a great deal of money, and the plans, even when prepared and adopted, can only be carried into effect gradually.

ANNUAL MEETING, SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

The tenth general meeting of the Society of Naval Architects and Marine Engineers, was held at the House of the American Society of Mechanical Engineers in New York city on Nov. 20 and 21, 1902. The attendance was large and fairly representative, and during the two days' sessions a programme of professional papers was considered, besides transacting the necessary business connected with the finances and membership of the society. The report of the Secretary-Treasurer of the society showed the finances to be in good condition, and that the membership had reached a total of 843. During the meeting about 100 new members were elected. Vote was then taken upon the recommendation of the Council to increase the entrance fee and annual dues of members and associates from $5 each to $10 each, and of juniors from $3 each to $5 each, and the result was an approval of the recommendation. On Friday evening a banquet was held at Delmonico's, and on Saturday there was an excursion to the works of the New York Shipbuilding Co., at Philadelphia. The professional papers in the order in which they were considered were as follows:

TECHNICAL TRAINING FOR SHIPBUILDERS.

This paper, by Dr. Henry S. Pritchett, President of the Massachusetts Institute of Technology, explained its purpose in the following paragraphs:

There is no need to-day to dwell upon the necessity of technical training for the naval architect and the marine engineer, and it may be admitted that the superintendent will be none the worse for such a training. There may be differences of opinion as to details, but there is not likely to be much dissent from the opinion that a part of the technical training of these men can be most economically obtained in some sort of a technical school. Let it be admitted that all these and the master shipbuilder (if there be one) shall be ranked as shipbuilders, together with their assistants and the young men who are growing up in the business, and let us see if there can be found a common body of technical training proper for all shipbuilders, and such as can be given in a technical school or college.

At the Massachusetts Institute of Technology those interested in the teaching of naval architecture and ship design have, during the past three years, tried to attack this problem specifically, not only in the interest of the course in naval architecture already established at the Institute, but also for the further reason that the Institute has been selected by the United States Navy Department as the place of instruction for officers ultimately to be assigned to the corps of Naval Constructors. In preparation for this instruction the whole question of technical training for builders of ships—whether merchant ships or ships of war—has been gone over afresh.

The paper then outlined briefly the work of the course in naval architecture which had been planned, and was now being carried out at the Institute.

The discussion was brief, and consisted in the further explanation of some of the details of the proposed course of instruction by members of the faculty of the Institute who were present.

PROGRESSIVE TRIALS OF FERRY-BOAT "EDGEWATER."

This paper, by Col. E. A. Stevens and Mr. C. P. Paulding, consisted mainly of a series of tables and diagrams recording the results of the trials of the vessel named.

PROBABLE FUTURE DEVELOPMENTS IN THE USE OF ELECTRICITY ON BOARD SHIPS.

This paper, by Mr. F. O. Blackwell, discussed, (1) the substitution of steam turbines for reciprocating engines for driving electric generators; (2) the use of alternating current generators and motors instead of continuous current apparatus; and (3) the operation of all auxiliary machinery on ships by electric motors. As the result of his discussion the author says:

In conclusion I think the steam turbine is the coming method of driving generators. Its rotary motion, light weight, small size and high efficiency at all loads make it particularly suitable for marine use. Alternators are best adapted to be driven by high speed turbines, but alternating current has both its merits and demerits. For transmitting power polyphase current is most economical, and the induction motor for constant speed cannot be equalled for simplicity of construction and ability to stand hard usage. It does not, however, permit of as economical or exact speed regulations as a continuous current motor, although there are possibilities of the development of an alternating commutating motor which will meet these requirements. As the majority of motors on shipboard run intermittently at variable speed the selection between continuous and alternating current should only be made after thorough investigation.

As to the more extended use of electricity for all purposes I have no doubts. It permits the concentration of the generation of power in one place and its easy distribution over any distance and its divisability into small or large amounts. The electric motor is efficient, reliable and clean. Its convenience and the ease with which it can be controlled make it suitable for every kind of service. Its universal adoption on shipboard will increase the economy of the ship, either making the coal supply more effective or giving increased weight applicable to guns or armor. But more important still, it will permit quicker and more accurate work with each piece of mechanism, and, therefore, adds to the efficiency of every man in the ship's crew.

The following two excerpts from the body of the paper touch on subjects which are of general interest outside of shipbuilding:

The steam turbine cannot be regarded as a general substitute for the reciprocating engine, as its speed is too high for direct connection to most machinery or for the safe use of gearing. For driving electric generators, however, it is ideal. Within reasonable limits the higher the speed of electrical apparatus the smaller, lighter and more efficient it becomes. We may even consider the electric motor and generator simply as a convenient speed-reducing and distributing mechanism which is more efficient than most mechanical connections.

Compared with the reciprocating engines and low-speed generators now used in our Navy, a turbine plant can be designed which will have but one-quarter the weight and take but one-tenth the space. It would also save weight in the structure of the ship on account of its lightness and freedom from vibration.

The steam turbine can be used with a high degree of superheat (when superheated steam comes into general marine use, as it undoubtedly will before long), because there are no labricated surfaces in contact with the steam, and a high vacuum can be obtained because there are no piston-rod packings to leak air. The entire absence of lubricating oil in the condensed steam is also a great advantage to avoid deterioration and foaming in boilers.

The efficiency is very high, especially when we consider that it is the actual efficiency, including all mechanical and electrical losses, there being no such thing as indicated horse-power in a turbine.

The steam consumption of, let us say, a 300 KW. turbo-alternator at full load with dry steam at 200 lbs. pressure and 28-in. vacuum would be about 20 lbs. of steam per KW. hour, or 15 lbs. per electrical horse-power hour. The steam consumption at one-half load would be about 22 lbs. per KW. hour. There is no objection, therefore, to putting in large units and running them much of the time underloaded.

In order to appreciate this it should be contrasted with the present reciprocating compound dynamo engines, which take 30 to 50 lbs. of steam per KW. hour at full load, and 40 to 65 lbs. at one-half load. It is at least as efficient as the main engines at full power and undoubtedly much better than they are at cruising speed.

Of course, it should not be forgotten that the average ship dynamo and engine now in use is from 30 to 100 KW. capacity, and also that the high speed alternator has a higher efficiency than the slow speed continuous current generator, especially at low potentials when the commutator brush friction is high. . . . . .

Centrifugal pumps have recently been built in England and this country for heads up to 500 ft. lift by [illegible] high speeds and having a number of runners in [illegible]. There will soon be no difficulty in obtaining these to replace reciprocating pumps for all purposes on [illegible] board with practically the same efficiencies and [illegible] but one-third the weight. These pumps are particularly well adapted to be run by electric motors. Their high speed gives a small and efficient motor. They avoid entirely all gearing, valves and reciprocating parts, and consequently, much of the noise, vibration and repairs of reciprocating pumps. They do not require much variation in speed in order to largely change their capacity. They can be used to maintain nearly constant pressure at constant speed with a variable delivery. If the outlet is closed, there is no great increase in pressure and the pump unloads itself like a blower. If the outlet is partially opened the pressure decreases somewhat and the pump begins to feed. With a constant head a small variation of speed will make all the difference between the pumps delivering full capacity and doing no work. With such pumps available there need be no reciprocating pumps on shipboard with the exception of those for air. Where these centrifugal pumps are to be run at widely different pressures or capacities some of the runners may be cut out entirely or put in multiple with each other. Changeable pole motors can also be advantageously employed.

The discussion of this paper was brief. Rear Admiral Bowles, Chief Naval Constructor, expressed his substantial agreement with the author as to the general utility of electricity for operating auxiliaries, and referred to the fact that it was being employed on recent ships to operate the steering gear. On these same vessels centrifugal pumps were also substituted in several places were formerly it was the practice to use reciprocating pumps.

PRELIMINARY OFFICIAL TRIAL OF THE U. S. BATTLESHIP "MAINE."

This paper, by Assistant Naval Constructor J. W. Powell, described the preliminary trial trip of the battleship "Maine," which took place between Aug. 15 and 25, 1902. The observations made comprised: (1) The inspection of the vessel to determine the serviceability and habitability; (2) the engine trials, consisting of a 4-hour speed run over a measured course and reversing tests; (3) tests of the steering engine and manoeuvring qualities; and (4) test of the windlass and anchor handling gear. Regarding ventilation and temperature conditions,

Observations were made on the natural and artificial ventilation throughout the vessel, with the most satisfactory results. In every case, on the berth deck and on the flats below, all openings into the engine and boiler room trunks, and the dynamo and steering engine rooms, acted as intakes, with the result that the berth-deck passage, ammunition passages, etc., show no appreciable rise in temperature, while the natural and artificial ventilation (plenum system) of all the living and working spaces of the ship below the main deck leave nothing to be desired, so far as delivery of fresh air is concerned.

The following is a summary of the data obtained during the speed trial:

		First run.	Average.	Second run.
Max. revs. per min....	Port....	128.6	.....	131.6
	Strboard	128.1	.....	129.9
Avg. revs. per min..	Port....	127.25	.....	130.38
	Strboard	125.5	.....	128.5
Max. steam pressure at boilers		222.0	216.0	227.0
Max. steam pressure at engines	Port....	200.0	194.2	210.0
	Strboard	200.0	199.0	210.0
Max. air pressure, fire rooms.		0.31	0.214	0.28
Time on run, hrs., mins., secs..		1:54:04	.....	1:46:36
Actual distance run, knots.....		33.786	.....	32.388
True speed, knots.....		17.772	.....	18.228

THE WATER-TUBE BOILER IN THE AMERICAN MERCANTILE MARINE.

This paper, by Mr. Wm. A. Fairburn, was of great length, and gave a very comprehensive discussion of the history, requirements, practical success and advantage and disadvantages of water-tube boilers for mercantile vessels. Some brief extracts from the paper are given in another column of this issue.

SOME MATHEMATICAL PAPERS.

The three papers next read were of such special interest, and were so essentially mathematical that we give only their titles and authors as follows: "Longitudinal Bending Stress on Damaged Ships," by Geo. C. Cook; "Some Problems on the Surfaces of Buoyancy and of Water Lines," by Prof. C. H. Peabody; "The Vibrations of Steamships, with Special Reference to those of Second

and Higher Period," by Rear-Admiral Geo. W. Melville.

REMARKS ON THE NEW DESIGNS OF NAVAL VESSELS.

This paper, by Rear-Admiral Francis T. Bowles, Chief Constructor U. S. N., gave an interesting and instructive comparison between the most recent designs for U. S. battleship and armored cruisers, and those of former dates. We shall print it in a later issue.

TACTICS OF THE GUN.

This paper, by Lieutenant-Commander A. P. Niblack, U. S. N., was a somewhat technical discussion of naval tactics, particularly with reference to efficiency of gun fire, and consequently was largely of professional interest only. Perhaps the most interesting facts to the general reader, which the paper brought out, were those relating to marksmanship, which were as follows:

Few people realize the horrible destructiveness of modern gun-fire. Our fleet at Santiago accomplished what it did with less than 4% of hits, and at that time our navy had the reputation of having the best gunners in the world. Since then both ordnance and gunnery have been almost revolutionized, so much so that guns and methods good enough for 1898 are an invitation to-day to disastrous and bitter defeat. To illustrate how gunnery has improved and how terrible must be the hail of projectiles in a modern fleet engagement, let us briefly notice the recent progress made in the British navy in the matter of target practice. Let us take first the 6-in. guns, as shown by the annual prize-firing contest for 1901.

Each ship steamed at a speed of twelve knots and fired for two minutes with each 6-in. gun, firing one gun at a time, at a target 20 ft. long and 16 ft. high, at a distance of nearly a statute mile. As published in the British press and verified by official reports, in 1901 the average of 48 British ships was nearly two hits per gun per minute. The best 15 of the 48 made from two to four hits per gun per minute, but the best individual record was a string of eight shots and eight hits in one minute.

The record in the British navy for 6-in. guns for the year 1902, so far as published (and the record is, of course, not yet complete), is as follows:

Ship.	No. guns.	Shots.	Hits.	Per minute, Shots.	Per minute, Hits.	Hits.
"Ocean"	12	163	117	6.79	4.875	71%
"Crescent"	12	139	105	5.79	4.375	74%
"Goliath"	12	163	71	6.79	2.958	43%
"Terrible"	12	109	66	4.54	2.750	60%
"Blenheim"	10	84	50	4.20	2.500	59%
"Albion"	12	117	57	4.87	2.375	48%
"Cressy"	12	92	52	4.83	2.170	56%
Total	82	867	518			

In other words, 82 6-in. guns fired 867 projectiles in two minutes and made 518 hits, or nearly 60%. The "Ocean" averaged nearly five hits a minute. One of her gun captains fired 9 shots and made 9 hits in one minute This is easily the world's record, as it means less than 7 seconds between aimed shots. One gun fired 17 shots in two minutes and made 15 hits. It will be seen that the percentage of hits does not determine the standing of a ship. It is the number of actual hits per gun per minute. In smaller caliber guns one ship, in 1901, fired 159 shots in one minute from her 4.7-in. guns and made 114 hits, or 7.5 shots and 5.7 hits per gun per minute. In larger calibers the "Ocean" this year made 68% of hits with her 12-in. guns, and one ship in the British navy has a record of 8 shots and 7 hits with her 12-in. guns in 5 mins. and 30 secs. Indeed, the established firing interval for British 12-in. guns is about 48 secs.

WHY IT TAKES SO LONG TO BUILD AND EQUIP A NAVAL VESSEL FOR THE UNITED STATES.

This paper, by Mr. Geo. W. Dickie, undertook to lay the burden of delay in constructing naval vessels upon the system of divided responsibility which is in practice in the Bureau of Construction. The argument is quite well explained by the following excerpt:

There should only be one naval architect responsible for the design of the vessel outside of her propelling machinery. Now we have three parties trying to do the work. The bureau of construction and repair, the superintending constructor, and the shipbuilder, and much time is lost in trying to harmonize the ideas of these three parties to the design. As the bureau of construction must finally decide, the time expended by the other two parties is in many cases simply wasted, and retards construction work on the vessel.

The paper caused a rather heated discussion, consisting mostly of argument and data in rebuttal to those presented in the paper.

The closing papers comprised two of special interest on "Measurement Rules for Yachts, with Special Reference to Racing Conditions," by F. W. Belknap; and on "The Balancing of Valve Guns," and a third on "Submarine Torpedo Boats—Past, Present and Future," by Mr. Lawrence Spear, which we shall abstract in a future issue.

THE NEW YORK TOWER FOUNDATIONS FOR THE MANHATTAN BRIDGE.

Bids for constructing the New York tower foundations for the Manhattan Bridge across the East River at New York city will be received on Dec. 11, 1902. The Manhattan Bridge is to be a suspension bridge with a clear span of 1,600 ft., and the main towers will be steel framework structures resting on masonry piers founded on timber caissons sunk by the pneumatic process. The Brooklyn pier and caisson are now in process of construction, and the present bids are to be made for the corresponding work on the Manhattan side of the river.

Briefly described, the caisson is to be 78 × 144 ft. in plan and 44 ft. 6 ins. high, and is to be constructed of long-leafed southern pine. The general construction of this caisson is described as follows in the specifications:

WALL CONSTRUCTION.—The lower edge of the outside walls shall consist of a 12-in. × 22-in. timber, with one edge chamfered 6 ins. × 8 ins.; the lower face of this timber will be reinforced by a 3-in. × 14-in. oak plank. On top of the 12-in. × 22-in. timber will be laid a course of 6-in. × 24-in. timber, and above this course will come the regular outside wall construction of 12 ins. × 12 ins. laid horizontally, breaking joints at least 6 ft. An inside wall of 12-in. × 12-in. timbers set vertically will extend from the 6-in. × 24-in. timber up into the roof, and every other timber of this wall will continue to a height of 22 ft., and every sixth timber with halved joints shall extend to the top of the caisson. The 12-in. × 22-in. edge timber shall be fastened to the walls of caisson with 1-in. screw bolts, staggered and spaced 3 ft. c. to c., extending to the top of the second course of 12-in. × 12-in. outside wall timber.

All outside wall timbers to the launching height, 27 ft. 6 ins. above lower edge, shall be drift bolted with 1-in. × 30-in. drift bolts, started in each course, staggered and spaced 3 ft. c. to c. From this point to top of caisson all horizontal wall timbers shall have 1-in. × 30-in. drift bolts started in each course, staggered and spaced 4 ft. c. to c. The pitch of the drift bolts in each course shall be varied with the courses below, so as to secure an equal distribution of drift bolts throughout the walls. The vertical wall timbers shall be secured to the outside wall timbers with 1-in. × 20-in. drift bolts spaced 24 ins. c. to c.

The ends of the 22-ft. timbers, the halved joints of the vertical timbers, extending to the top of the caisson, and the intersection of vertical timbers with the horizontal crib timbers, are to be fastened with 1-in. screw bolts. The vertical corner timber shall be fastened in a similar manner to the outside wall timbers with 1-in. × 20-in. drift bolts, spaced 12 ins. c. to c., and the halved joints fastened with 1-in. screw bolts. The lower ends of all vertical wall timbers at the cutting edge are to be halved for 18 ins. to receive 9-in. × 18-in. housing timber, which shall be framed into knee braces and bolted to outside wall timber with one 1-in. screw bolt.

The outside sheathing of these walls will be two courses of 3-in. × 12-in. tongued and grooved sheathing, fastened with ⅝-in. × 7-in. wrought iron boat spikes staggered 9 ins. c. to c., the first course to be laid diagonally, and the second or outside course vertically; all joints to be broken at least 6 ft.

The cutting edge will be protected by an 11-in. × 24-in. × ½-in. angle plate, fastened to the bottom and sides of the walls, with 7-16-in. × 12-in. wrought iron spikes with countersunk heads, staggered and spaced 18 ins. c. to c. The corners of caisson shall be protected with ⅜-in. × 39-in. steel plate for 20 ft. above lower edge, and to top with ¼-in. × 39-in. steel plate fastened with ⅜-in. × 6-in. wrought iron boat spikes.

BULKHEADS, KNEE BRACES AND STRUTS.—The working chamber will be divided by two longitudinal bulkheads, and the walls of chamber will be braced to the roof and stiffened with diagonal knees, auxiliary bulkheads and transverse horizontal struts. The longitudinal bulkheads shall be constructed with a depth of 6 ft. 9 ins. from sheathing of roof, and with two walls of 12-in. × 12-in. timber, drift-bolted, as described for outside walls of caisson below launching height, sheathed with 3-in. × 12-in. diagonal sheathing on each side of bulkhead, fastened with ⅝-in. × 7-in. wrought iron boat spikes, staggered 12 ins. c. to c.

The bottom and top courses of the bulkheads shall be framed into the walls of caisson with halved and dovetailed joints, and drift-bolted to the same. All intermediate joints of the top and bottom courses shall be halved, and the several timbers of these courses shall be fastened together in a horizontal plane with 1-in. screw bolts spaced 3 ft. c. to c. The intermediate courses between shall have plain butt joints and shall be bolted through the sheathing in the same manner with 1-in. screw bolts spaced 3 ft. c. to c., in a horizontal line, in each course of timber.

The auxiliary bulkheads shall be located between the longitudinal bulkheads and extending from the end walls of caisson to the first transverse 16-in. × 18-in. horizontal strut. They shall have the same depth as the longitudinal bulkheads, and be built up with one wall of 12-in. × 12-in. timber, drift-bolted in the same manner and framed and screw-bolted in their upper courses, as described for the longitudinal bulkheads. The ends of both longitudinal bulkheads and auxiliary bulkheads shall be secured to the walls of the caisson with two 2½-in. rods at each end for the longitudinal bulkheads, and two 1½-in. rods for the auxiliary bulkheads.

The knee braces of side walls shall extend from a 12-in. × 12-in. roof sill diagonally to the top of the 6-in. × 24-in. timber in lower edge of wall, except where they occur in the same vertical plane as the transverse 16-in. × 18-in. struts, when they shall be framed in on top of this timber. These knee braces shall be built solid of two 12-in. × 12-in. timbers for the lower course, and two courses of 12 ins. × 16 ins. to fill the remaining space to the roof and sides of the chamber. The upper ends of these braces shall be cut in against the roof lining and chock blocks, and the lower ends shall cut in against the vertical side wall timber, the lower course extending through and resting on the 6-in. × 24-in. edge timber of walls. The ends of the 12-in. × 12-in. shall be drift-bolted to the roof and side walls with two 1-in. × 24-in. drift bolts at each end. The chock blocks at the upper ends of the lower courses shall be 9 ins. × 11 ins. of oak, and drift-bolted to the roof with seven 1-in. × 20-in. drift bolts; and the knees shall also be secured with two 1½-in. rods to each knee, except at corners, where one 1¾-in. rod will be used, passing from the 12-in. × 12-in. sill timber through to the outside of walls of the caisson.

Eight lines of transverse struts of 16-in. × 18-in. timber shall extend across from side to side of caisson, and be framed into side walls on top of the 12-in. × 22-in. edge timber. These struts shall be supplemented with two 2½-in. rods to each strut, extending from outside to outside of caisson walls, and to have turnbuckles. These transverse struts are to be secured to the roof with vertical posts, braces and rods.

ROOF.—The roof shall consist of a sill course of 12-in. × 12-in. timber framed and secured to walls, bulkheads and knee braces. On top of this sill course shall be laid a course of 12-in. × 12-in. timber, which shall be laid as close as possible and secured to sills with 1-in. × 20-in. drift bolts. Every second timber in this course shall extend through the vertical wall timbers of caisson, and every sixth timber shall extend to the outside of caisson walls and be framed into it with a dovetail head; the other timbers will be cut off at the inside of the vertical wall timbers. The ends of all timbers will be secured to sills and walls with 1-in. × 20-in. and 1-in. × 30-in. drift bolts, respectively. On top of this course of timber shall be laid two courses of 3-in. × 12-in. tongued and grooved diagonal planking, the first course to be laid at an angle of 45° to the transverse timber and spiked to them with ⅝-in. × 7-in. wrought iron boat spikes staggered and spaced 18 ins. c. to c. The second course of 3-in. planking shall be laid at right angles to the first course, and shall be fastened in a similar manner.

On top of this planking shall be laid a course of 12-in. × 12-in. timbers, laid longitudinally and framed and secured to side walls, as described for the first course of timber. This course will be drift-bolted to the planking and timber below with 1-in. × 28-in. drift bolts, spaced 3 ft. c. to c. These two courses of timber and the planking shall be screw-bolted together, and to the sill course with 1-in. screw bolts. The ceiling of the roof between sills and the side walls of chamber, between housing timber, sills and knee braces, shall be lined with 3-in. × 12-in. plank, dressed four sides, and fastened to 12-in. timber with ⅝-in. x 7-in. wrought iron boat spikes, staggered 8 ins. c. to c. The spaces in the ceiling between the sills and knee braces shall be filled, solid and flush with the under side of sills, with timber.

CAULKING.—The outside seams of horizontal wall timbers, and all chamber seams in vertical wall timber and roof timber, and in roof and wall lining, shall be caulked with two threads of cotton, followed with four threads of oakum, the several threads to be thoroughly driven home, and all joints, as far as practicable, to be served with hot pitch. Special care shall be exercised to caulk vertical wall timbers at the knee braces and bulkhead ends before these members are put up, and the top course of all bulkheads shall have the upper seams caulked before any 12-in. × 12-in. roof timber is put in place. All caulked joints shall be chamfered to facilitate proper caulking.

CRIBBING.—The cribbing, from the roof to the launching height, shall be of alternate longitudinal and transverse courses of 12-in. × 12-in. timbers, in which all splices shall be halved joints, occurring at intersections. Crib timbers will be framed into outside walls with dovetailed heads, and be bolted to vertical wall timbers, as

described above, with 1-in. screw bolts. At all intersections each course will be drift-bolted to the courses below with one 1-in. × 30-in. drift bolt at each intersection.

Each bay of each line of cribbing shall have diagonal braces, one on either side, of 3-in. × 12-in. plank, fastened to each intermediate timber with two ½-in. × 7-in. wrought iron boat spikes, and to end timbers by three ½-in. × 7-in. boat spikes. Above the launching height the cribbing shall be spaced vertically, and to the height of 16 ft. above it shall have 3-in. × 12-in. diagonal braces. All cribbing and bracing above launching height shall be bolted and spiked in a manner similar to that specified for cribbing below.

COFFERDAM.—A cofferdam constructed in three sections shall be attached to the caisson during the progress of the work. The first section shall have solid walls of 10-in. × 12-in. horizontal timber, breaking joints at least 12 ft. with vertical wall timbers of 12 ins. × 18 ins., spaced 12 ft. c. to c. The horizontal timber will have 1-in. × 30-in. drift bolts started in each course and spaced 4 ft. c. to c., with one drift bolt on either side of butt joints. The vertical wall timbers shall be drift-bolted to outside walls with 1-in. × 20-in. drift bolts, spaced 24 ins. c. to c., and have long halved splices at rod girts; these splices will be fastened with 1-in. screw bolts either side of joint.

The first two sections of cofferdam will have the outside joints of wall timber caulked, as described for caisson walls. The second and third sections shall have walls of similar construction, with the exception of the horizontal wall timbers in the third section, which shall be 8 ins. × 12 ins. The rod girts of all sections shall be 12 ins. × 18 ins. The outside sheathing shall be similar in kind and fastening to that specified for the walls of the caisson.

The cribbing shall consist of 12-in. × 12-in. timbers in longitudinal and transverse courses, with 3-in. × 12-in. diagonal bracing in each bay of 12 ft. These courses shall intersect in the same plane, the transverse timbers to have halved splices 1 ft. long, screw-bolted with one ¾-in. screw bolt, and have splices of two 3-in. × 12-in. × 4-ft. planks spiked to each side with twenty-four ⅝-in. × 7-in. wrought iron spikes. The longitudinal timbers shall butt against these timbers and to have splices of two 3-in. × 12-in. × 4-ft. planks spiked to both longitudinal and transverse timbers, with at least 24 ⅝-in. × 7-in. wrought iron boat spikes. The diagonals shall be spiked to cribbing and wall timbers with ½-in. × 7-in. spikes.

In the corners there shall be drift-bolted, with one 1-in. drift bolt in each wall timber, two pieces of 6-in. × 12-in. and one piece of 12-in. × 12-in. timber, and each section of cofferdam at each corner shall have three sets of wedging irons securely fastened to the 12-in. × 12-in. and 6-in. × 12-in. timbers, with two ¾-in. × 12-in. lag screws in each flange or wedge irons, and each set of wedge irons shall be provided with tough oak wedges, as indicated by detail drawings.

The first section of cofferdam shall be secured to the caisson by outside wedge clamps made of ¾-in. iron, and secured to cofferdam and caisson with ¾ × 8-in. lag screws; these clamps shall be placed, two at each corner and opposite each vertical wall timber of cofferdam. The several sections will be secured to each other with 1-in. rods passing through the 12-in. × 18-in. rod girts, using two rods to each corner bay and one rod to each intermediate bay between vertical wall timbers.

The caissons are to be filled with concrete composed of one part Portland cement, 2½ parts sand and five parts broken stone, to a height of 47.79 ft. above the cutting edge. Above this level the pier will be of limestone masonry to a point 8½ ft. below mean high water, and of granite masonry backed with limestone above this point to the finishing courses, which are to be of granite.

Complete specifications and plans for the work described above can be secured by bidders from the Department of Bridges, New York city, Mr. Gustav Lindenthal, M. Am. Soc. C. E., Commissioner, and Mr. H. A. La Chicotte, Engineer in Charge.

THE SULPHUROUS ANHYDRIDE WASTE-HEAT ENGINE.*

By Edward F. Miller,† M. Am. Soc. M. E.

Professor Hollis spoke early in the afternoon on the fact that about 60 to 70% of the heat of the coal goes into the ocean in the case of the steamship. The subject I am to speak on is how we can recover some of that 60 or 70% which goes to waste. First, let us consider the ordinary steam engine and see what its limitations are.

The efficiency of any heating machine is evidently the quotient of the heat transformed into work divided by the heat received, or,

$$\frac{\text{(heat supplied} - \text{heat exhausted)}}{\text{heat supplied}} = \text{efficiency \%}.$$

It has been shown by theoretical discussion that for what is called the perfect engine, the efficiency is proportional to the ratio of the temperature worked through to the absolute temperature of the source of supply.

As an illustration, let us take the case of the steam engine using steam at 165 lbs. absolute pressure and exhaust at 26 ins. vacuum, and see what would be the efficiency of the theoretically perfect engine. Such an engine is supposed to be an engine which has no losses—no cylinder condensation, no radiation, and the walls of the cylinder are supposed to absorb no heat. Such an engine is called the theoretically perfect or Carnot engine. The efficiency of such an engine would be the temperature of supply minus the temperature of exhaust divided by the temperature of supply. Taking the temperatures of the steam at the two pressures given and adding 460.7° to reduce the temperature to absolute zero, we get as the efficiency of the perfect steam engine 29%. The actual engine, on account of its cylinder condensation and radiation, realizes only 80% of this and has a thermal efficiency of 23%.

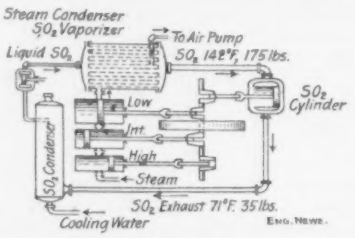


Fig. 1. Diagram Illustrating Arrangement of Triple-Expansion Steam Engine with Sulphuric Anhydride Attachment.

Attempts have been made recently to increase the efficiency by raising the temperature of the incoming steam. In Germany it is the custom now in modern plants to superheat the steam by 300° F. and that raises the efficiency. A perfect engine working through the range from 300° F. to the same exhaust temperature as before would have 48% efficiency. Taking 80% of that we have about 38% as the efficiency of the actual engine; but, of course, if you superheat the steam it means that you must have an extra furnace, and that means that the cost of a pound of superheated steam is more than the cost of a pound of saturated steam.

It is only recently that attempts have been made to increase the efficiency by lowering the temperature of the exhaust. Evidently in the formula you can raise the efficiency by either raising the temperature of the source of supply or lowering the temperature of the exhaust, and the subject on which I am to speak is the method by which the temperature of the exhaust can be lowered so that the initial range of temperature can be made greater.

If you will consider the expression for efficiency for a moment you will see that for an engine to have an efficiency of 100% the engine must transform all the heat it receives into work. It must exhaust no heat. It must exhaust at the absolute zero of temperature or 460.7° below zero Fahrenheit. You can see from that that the actual steam engine, even although it may have the greatest efficiency possible, must necessarily have a limit to its efficiency. Now consider the case again. The best vacuum that we ordinarily maintain from day to day is about 26 ins. That means the temperature of the steam leaving is 126.3° F. Cooling water for the condenser entering, say, at 70 will leave the condenser somewhere in the vicinity of 130° F. If you maintain a vacuum of 26 ins., of course your cooling water will leave at a temperature much higher than 126°.

Instead of using cooling water in the condenser we use sulphurous anhydride. Sulphurous anhydride at the ordinary temperature is a gas, colorless like air, has a peculiar odor of sulphur and can be easily liquefied at the ordinary temperature by applying a pressure of about 25 lbs.; SO_2 we call it in chemistry, one atom of sulphur and two of oxygen in a molecule. In the sulphurous anhydride engine the SO_2 is used in the place of the cooling water in a surface condenser. The sulphurous anhydride is vaporized and the SO_2 is used in a separate cylinder. This cylinder gives power which is utilized, and then the SO_2 from this separate cylinder passes to another condenser where it is condensed by cooling water, and then the liquid SO_2 is again pumped back into the vaporizer or condenser, so the SO_2 is used over and over again.

Fig. 1 is a diagram illustrating the arrangement of the parts for a triple-expansion engine with sulphuric anhydride attachment. The low-pressure cylinder exhausts into a surface condenser, made specially for the liquid sulphurous anhydride, which passes in at the left, as indicated by the arrow. The steam is condensed with a vacuum maintained on the low-pressure cylinder by means of an ordinary air pump. The heat given up by the steam in condensing serves to vaporize the sulphurous anhydride, and a pressure of something like 175 lbs. on the sulphurous anhydride vapor is maintained in this surface condenser. That vapor passes to the cylinder at the right where it is used, and from the cylinder at the right it exhausts into the condenser at the left, which is nothing but a surface condenser. After being subjected to a pressure of 40 lbs. the liquid is pumped by a small pump back into the vaporizer, thus making a complete cycle.

To understand fully the action there we can best do it by referring to the pressure curves of the SO_2 and steam (Fig. 2). The curve at the bottom shows the pressure of steam as ordinates for temperatures as marked on abscissas. You will note at 180° the pressure of the steam is only 7.5 lbs., whereas the pressure of sulphurous anhydride is something like 270 lbs. At 100° F. the pressure of sulphurous anhydride, you see, is something like 80 lbs. You will also notice that the total heat of sulphurous anhydride is very much lower than that of steam. On the same scale, the total heat of a pound of steam ranges in the neighborhood of 1,100, and of sulphurous

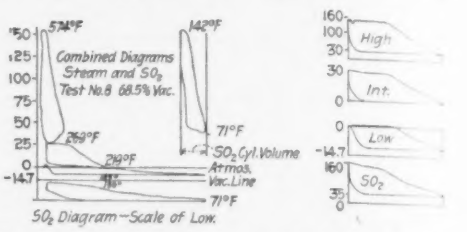


Fig. 3. Indicator Diagrams from Sulphuric Anhydride Engine.

anhydride 190. This, of course, will make it evident that it is possible to vaporize sulphurous anyhydride and get excessive pressure with it, the fact being that the total heat of sulphurous anhydride is low and its pressure rises rapidly with rising temperature.

I have here some indicator cards which were taken from the engine. The sulphurous anhydride card is shown at the bottom. The initial pressure in the cylinder was 160 lbs., the back pressure approximately 135 lbs. The size of the sulphurous anhydride cylinder was just about the same as that of the high-pressure cylinder of the steam engine, and we realized from it about the same amount of work that we realized from that cylinder of the triple-expansion engine.

The cards I have shown are taken from test No. 8 in the accompanying table. This represents a series of tests made by Prof. E. Josse, of the Kgl. Tech. Hochschule, of Berlin, Germany, a man whose word is taken as the highest authority in the engineering line in Berlin. The values I have changed over so that they are in English units. The engine which he designed was about 175 HP. and the steam supplied to the engine was superheated some 200° to 300° in the test. You will notice that the power developed by the SO_2 cylinder was between 30 and 40% of the power developed by the steam engine. With the ordinary steam engine the range of temperature is from 366° down to 126°. What have we done here? We have lowered the temperature of the exhaust of the combined engine down to 71°, the temperature of the SO_2 leaving the last cylinder. Suppose we substitute in the formula for efficiency; instead of having 587° as absolute temperature of the exhaust we have 530.7°, or for the perfect steam

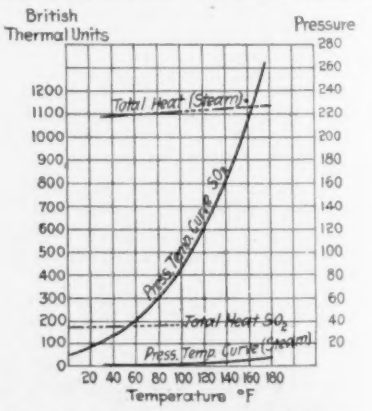


Fig. 2. Pressure-Temperature Curves of Steam and Sulphuric Anhydride (SO_2).

engine using saturated steam, 36% efficiency against 29%. In the second case the steam engine with steam superheated 300° F. gives an efficiency of 48% against 38% for the actual engine.

It has been found experimentally that instead of running the steam engine with the greatest possible vacuum you can get, it is better to run with a 70% vacuum, or, say, 20 to 21 ins., and let the SO_2 cylinder do extra work. By referring to the curve of SO_2 pressures you will notice that after you get to about 100° F., the curve rises steeper than it does at the first part. That means you can get greater pressure in your SO_2 cylinder if you carry less vacuum at a higher temperature in the discharge from the low-pressure cylinder. It is a matter which has to be

*From a paper read before the New England Water-Works Association, Nov. 12.

†Associate Professor of Steam Engineering, Massachusetts Institute of Technology, Boston, Mass.

determined for each particular engine—what is the best vacuum for the output, but as far as those engines have been tested the best vacuum for economy is in the vicinity of 70%.

This device can be attached to any engine. The only thing needed is a safe, strong surface condenser to stand the pressure which you realize in the vaporizer by the first condenser where the exhaust steam is condensed.

You might say that when combined with water this SO_2 gas makes sulphurous acid, but there is no danger from any acid being formed. As to the leakage of SO_2, as the pressure of the SO_2 is always greater than the pressure against it, the tendency will be for the SO_2 to leak outwards, and should it leak outwards in the vaporizer it would immediately pass into the condensed steam which is constantly changing, so when the SO_2 combined with water it would pass off to the pump and be changing all the time. If it leaks into the other condenser where the pressure is 40 lbs., it would go into the cooling water, changing all the time, so you would simply lose a little SO_2. Besides its application to the steam engine, this invention can be applied in many other ways, as, for example, in the recovering of some of the waste heat of the exhaust of gas engines and of the heat from flue gases leaving a battery of boilers. There is no reason why the draft should not be maintained artificially and the heat going out with the furnace gases be absorbed by a vaporizer.

The probable field for this engine and its most direct way into the market will be through its application to the gas engine. The ordinary gas engine gives a higher thermal efficiency than the steam engine, and the efficiency of the gas engines does not depend on the load, as in the case of the steam. The efficiency of a gas engine when running light does not vary materially from when running heavily loaded. You often see the exhaust pipe of a gas engine of a dull cherry red color, which means a large loss of heat.

There has been built in Germany a large engine of this class applied to a gas engine. They are going to take the efficiency of the gas engine as it is and recover as much as possible of the waste heat of the gas engine by passing it through an SO_2 vaporizer. In this connection I may add that the steam engine of this class has hardly passed the experimental stage. There have been three built which have been in use less than a year. There has been one run constantly day and night for about a year in an electric light station in Berlin. The other engines have been built mostly for experimental work, and the earlier one was simply an old steam engine altered over.

The only difficulty so far has been in the method of packing the piston rod of the sulphurous anhydride cylinder. The difficulty was not a great one, but it made it uncomfortable to work in the engine room if there was a leak of SO_2, and the stuffing boxes had to be absolutely tight. The trouble has been overcome by making the stuffing boxes in two parts.

(A recent report of U. S. Consul-General Frank H. Mason, of Berlin, gave additional particulars concerning the waste-heat engine at the Berlin Electrical Works. We extract the following from the report.—Ed. Eng. News.)

A cold-vapor-engine plant has been constructed, put in operation, and tested in actual daily service at the central station of the Berlin Electrical Works in Markgrafen Strasse. This is the oldest of the power stations of the company, and is equipped with what is now considered relatively small units, viz., vertical compound engines of 360 HP., of Belgian construction, which have an average steam consumption of 18.35 lbs. per I. HP. hour. With a steam consumption as high as this, there is abundant chance for economy by utilizing the waste heat. Moreover, this was a case in which more power was urgently needed at the station. Either the cold-vapor auxiliary plant or new steam boiler and engine had to be supplied.

Accordingly, a cold-vapor engine of 175 HP. was built by Freund, of Berlin, and put in operation in May of this year. It is a single, horizontal cylinder machine, the piston being 17¾ ins. in diameter, with 20-in. stroke, and, unlike the smaller engine at Charlottenburg, is geared independently to a directly coupled dynamo, which feeds into the service cables of the company. Working thus as a separate unit, the efficiency of the cold-vapor engine can be measured and recorded with great precision, and the net result may be condensed into the statement that at an average speed of 130 revolutions per minute it delivers 150 brake HP.—an addition of 41.7% to the working energy of the compound steam engine, from which it receives and utilizes the waste heat in form of exhaust steam. What this means will be made more plain when it is considered that the combined power stations of the Berlin Electrical Supply Company contain steam engines which, with an average steam consumption of 12.3 lbs. per I. HP. hour, have a total output of 142,300 HP., to which, by the use of cold-vapor engines, there may be added 55,000 HP. without increasing by so much as a pound the consumption of coal. The system adapts itself with especial readiness to large plants which, like power and lighting stations in growing cities and towns, have to meet a steadily increasing demand for current. This the cold-vapor engine enables them to do without increase of boiler or steam engine capacity by simply saving heat energy which has previously gone to waste.

Although it has been from the first in careful and scientific hands, it need hardly be said that the dioxide-vapor engine is as yet in the infancy of its development and application. It has been regarded with skepticism and incredulity by most practical engineers in this country, but these have yielded to the hard logic of its demonstrated efficiency. It has not yet been tested on shipboard, but it is believed that in view of the tremendous losses of heat energy in the condensers of an ocean greyhound, the abundance of cooling water, and with all the incentive to fuel economy at sea, its most important future application may be in connection with marine engines. It has not yet been tested with the waste heat of furnaces, although it is well known that even in the best installations from 20 to 25% of the thermal energy generated by the burning coal escapes up the chimney. The burnt gases and heated cooling water of gas engines are also a leak of wasted energy which the cold-vapor engine may in future serve to close. Experience shows that in an average gas engine, not more than 26% of the thermal energy of the gas is transformed into work, while 71% is carried off in the waste gases and water of circulation. The gas engine is only less wasteful than the steam engine; both leave a wide margin of loss to be garnered and saved by the resources of modern science.

The report of Professor Josse, from which the foregoing results are derived, goes extensively into the question of comparative costs of installation. Condensed to their most concise compass, his conclusions are that a combined steam-waste heat plant of 1,000 HP., including compound steam engines of 1,200 I. HP. and a cold-vapor plant of 400 I. HP., complete in every detail, would cost in Germany 212,000 marks ($50,456), while a triple-expansion steam engine of 1,600 HP., without vapor engine, would cost 206,000 marks ($49,028), a difference of only $1,424, which, with steam coal at $4.15 per ton, as at Berlin, would be saved in a short time by the cold-vapor auxiliary.

Coming down to actual facts, the net cost of the 175 HP. waste-heat-engine plant at the Markgrafen street power station was 49,700 marks ($11,828.60), and of a gas-engine plant, also of 175 HP., 47,625 marks ($11,334.75), a difference so slight as to be negligible in presence of other and more important considerations.

Tests on a "Waste Heat Engine," Consisting of a Triple-Expansion Condensing Steam Engine with a Sulphurous Anhydride Heat-Swing Cylinder Attached. Made by Prof. E. Josse, of the Kgl. Technische Hochschule, Berlin, Germany.

* Arrangement of Apparatus during the Test		Steam engine working triple expansion							Steam engine working compound				
		Water from the condensation traps led into the vaporizer					into the discharge pipes	dry saturated	Water from the condensation traps led into the vaporizer				
		Superheated Steam							Superheated Steam				
				with high vacuum								with small quantity of circulating water	at half Load
Speed — r. p. m.		139.6	136.3	143.5	137.4	145.	145.	148.	148.	149.	137.	148.	137.	146.
Volts at Dynamo		210.	189.5	210.	191.	209.	212.	221.	220.	220.	208.5	225.6	210.	220.
Amperes from Dynamo		900.	829.	584.	614.5	579.	576.4	610.	610.	609.5	508.7	531.	470.	272.
Steam Engine	Temperatures °F. Boiler steam — admission	534.	500.	500.	505.	479.	479.	500.	574.	373.	430.	619.	420.	616.
	Degrees — superheat	175.	219.	251.	274.	210.	210.	221.	294.		257.	287.	261.	267.
	Steam pressures Inlet pressure - High-press.cyl.- lbs. per sq. in. above atmos.	126.5	156.5	159.	156.5	156.5	106.5	106.5	156.	156.5	106.5	163.7	136.9	156.5
	Per cent vacuum in condenser	80.	80.5	70.	85.	79.5	69.	68.5	69.5	68.2	73.	69.1	70.2	75.2
	Indicated output Horse power High-pressure-cylinder	59.2	55.2	68.6	40.9	59.6	63.6	76.5	76.3	59.2	77.5	66.7	73.9	50.8
	Intermediate cylinder	46.3	39.7	43.2	31.3	42.4	41.1	42.8	45.0	47.3	—	—	—	—
	Low-pressure-cylinder	29.6	34.3	42.4	29.4	43.3	39.8	42.9	42.0	49.8	44.3	53.8	43.7	31.6
	Complete engine	130.1	125.2	154.2	101.6	145.3	144.5	161.0	163.2	156.3	121.8	120.5	117.6	82.4
	Steam consumption in lbs. per hour Condensation from the vaporizer	1672.	1465.	1661.	1465.	1980.	1994.	2130.	1775.	2502.	1049.	1985.	1612.	1197.
	Condensation from the steam jackets and receiver	—	—	—	—	—	—	—	367.	—	—	—	—	—
	Total Condensation	1672.	1465.	1661.	1465.	1980.	1994.	2130.	2142.	2502.	1049.	1985.	1612.	1197.
	per H. P. ind.	12.5	11.2	12.2	14.4	13.6	13.8	13.2	13.1	16.4	13.8	13.4	13.7	14.3
Waste-Heat-Engine	Temperatures °F. SO_2 vapour Admission to cylinder	132.0	133.7	151.7	122.7	137.3	157.1	155.1	158.9	153.5	152.8	155.4	154.2	147.9
	SO_2 liquid. Outlet from Condenser	66.2	68.8	67.6	64.4	68.5	67.6	68.0	65.6	70.0	64.6	66.9	75.2	65.1
	SO_2 pressures (above atmospheric in lbs. per sq. in.) Circulating water — inlet	49.6	49.9	49.9	50.2	50.2	50.2	50.2	50.2	50.2	50.2	50.2	50.0	50.0
	Circulating water — discharge	59.9	60.2	62.4	60.2	63.8	63.3	63.6	62.1	65.1	61.2	63.2	76.6	63.0
	in Vaporizer	132.	128.	172.	110.9	142.2	167.7	166.3	172.	180.6	177.7	183.4	180.6	164.9
	in Condenser	31.2	33.5	34.8	31.2	35.5	35.5	36.2	34.2	36.	33.2	34.8	46.2	33.1
	Indicated	45.3	42.8	56.8	31.0	50.1	57.6	61.3	54.7	66.0	48.0	55.6	60.8	39.6
	Output — H. P.													
	in per cent of steam-engine	34.4	34.2	37.0	30.8	34.8	40.0	37.9	33.3	42.1	39.4	39.8	34.6	37.2
	Consumption of waste steam per I. H. P. per hour lbs. Condensation from the steam jacket and receiver Taken in to the Vaporizer	36.8	32.8	33.2	47.3	39.8	34.6	34.8	—	38.9	34.4	33.0	39.8	39.1
	Led to the discharge pipes	—	—	—	—	—	—	—	32.8	—	—	—	—	—
Combined Engine	Output — H. P. Indicated	177.4	168.	211.	132.6	196.4	202.1	222.2	217.9	222.3	169.6	196.1	158.4	113.
	Effective	151.8	143.8	177.2	114.2	174.3	176.2	202.9	201.9	201.	150.6	180.2	141.9	89.7
	Electrical	140.9	134.	164.5	106.3	162.5	163.5	189.1	188.2	187.2	141.9	167.8	132.	83.7
	Total steam consumption per hour — lbs.	1622.	1465.	1661.	1465.	1980.	1994.	2130.	2142.	2502.	1049.	1985.	1612.	1197.
	Steam consumption per I. H. P. per hour — lbs.	9.7	8.36	8.6	11.03	10.12	9.86	9.58	9.83	11.3	9.7	9.6	10.22	10.6
	Quantity of circulating water in gallons Total per hour	—	11,000	13,000	—	12,486	11,330	12,469	12,384	13,210	12,144	12,056	5,256	8,140
	Per I. H. P. per hour for the comb. engine	—	69.5	61.6	—	63.8	56.1	55.9	57.7	59.9	71.9	61.5	33.6	71.9
	Mechanical Efficiency Electrical Output ÷ I. H. P.	79.5	80.1	78.	80.4	82.8	81.	84.6	86.	84.2	83.5	85.5	83.5	74.
	B. H. P.) ÷ I. H. P.	85.5	86.2	83.8	87.5	89.1	87.	90.5	92.5	90.5	89.5	92.	89.2	79.5
Number		1	2	3	4	5	6	7	8	9	10	11	12	13

*Dynamo efficiency assumed, 92%

A COMPETITIVE TEST OF STEAM BOILERS.

In our issue of Aug. 22, 1901, we described and illustrated a new water-tube boiler designed by Mr. J. C. Parker, of Philadelphia, and involving some radical departures from generally accepted theories of boiler design. The Parker boiler is of the "horizontal water-tube type," as it is commonly called; but while most boilers of this type have their tubes inclined from the horizontal, in the Parker boiler the tubes are really horizontal, and other means than the inclination of the tubes are used to cause circulation.

In other boilers of this type, such as the Babcock & Wilcox, Heine, Root, etc., the whole nest of tubes is connected "in parallel" to the overhead drum. In the Parker boiler, the tubes are connected "in series," so that the water circulates through each tier of tubes in succession. The theory on which this boiler is designed is in brief that the motion of the moving columns of water inside the boiler and of gases in contact with the heating surface should be, in general, in opposite directions, so that the gases before their exit will come in contact with the coolest surfaces and their available heat may thus be extracted as completely as possible.

The criticism which experts in boiler work have generally made of the design is that the tubes which are exposed directly to the fire are not filled with solid water, but with—probably—a mass of foam, and that these tubes would consequently be overheated and burnt. It is of considerable interest, therefore, to see how the boiler behaves in actual practice.

There has recently been made, at the power station of the Rapid Transit Co., in Philadelphia, a competitive test between a Parker boiler and one of the regular Babcock & Wilcox boilers with which the station is equipped. Particulars of this test and its results have been furnished to us at our request by the Parker Engine Co., with the approval of Mr. Wm. S. Twining, M. Am. Soc. M. E., Chief Engineer of the Union Traction Co., of Philadelphia, and we quote as follows from this statement:

In accordance with your request for information in regard to the contract tests of our boiler conducted by the Rapid Transit Co., in competition with one of their Babcock & Wilcox boilers, we forward you data, drawings, photos and samples of scale.

We guaranteed that our boiler would evaporate more water under equal conditions of operation than their boiler. (2) That our boiler would not scale as rapidly as theirs. (3) that our boiler would wash out its own tubes automatically and constantly while in operation. (4) That our steam would be dryer, and that it would be impossible to cause it to prime. (5) That our tubes would not burn or blister. (6) That our hand hole joints could be made quicker and could be turned to stop a leak under pressure with safety.

We agreed that the Traction Co. should conduct the tests and specified the following conditions:

1. Both boilers to be put in perfect condition.
2. To be operated simultaneously and under equal conditions.
3. A separator and calorimeter to be connected to each steam pipe to intercept and measure the entrained water.
4. Feed water to be unpurified city water from open heater or direct from mains.
5. Both boilers to be operated at maximum power for 30 days of 24 hours each, without stopping; any leaks or other injury to be repaired and charged against boiler together with time lost.
6. On the last day of trial the coal and water shall be weighed for 24 consecutive hours and the moisture in the steam deducted from the apparent evaporation, which shall then be computed for the full 30 days.

7. Both boilers shall then be opened, and whatever repairs or cleaning are necessary shall be done and charged against each respectively.

8. The net difference, if any in favor of the Parker steam generator, multiplied by 24, shall be deemed to represent the saving for two years, and the amount in dollars and cents, not exceeding . . . shall be due the Parker Engine Co. as a bonus in addition to the contract price.

The Parker boiler was started on July 26, but owing to the coal strike the Traction Co. were not able to get their boiler in condition before Sept. 1, when the test was started.

The tests of Sept. 1, 2 and 30 were conducted by Mr. Francis Head, assistant engineer of the company, in person, while in the others some of his assistants were present.

No attempt was made to get extraordinary results. The regular firemen were used and one man fired both boilers through his full eight-hour shift. The only instructions given were to treat both boilers exactly alike and whenever anything was done to one fire the other was to be immediately treated likewise. No one meddled with the fire-doors but the fireman himself. The fires were cleaned at the end of each shift by the regular gang who took the usual time.

The coal used was bituminous, run of mine, stated by the company chemist to contain 14,100 B. T. U. per pound. It was of a caking variety and had to be worked a good deal, and a great amount of clinker was taken out at each cleaning, a good deal of time being lost in this respect and in getting the fire burning properly afterward. The coal was weighed on the same scale in the same barrow, which held 125 lbs. net, not full enough to spill in wheeling. The floor was swept up and four barrows delivered to each boiler alternately, making 500 lbs. net delivered at a time.

To start and stop a test 500 lbs. of coal was put on the floor and the fire cleaned and the time and water taken when the fire was covered. The time of weighing the coal was taken but not the firing time.

All openings to the boilers through which leakage might occur were blanked and the feed pumps set over their own tanks so that the leakage from them would not be lost. The water was weighed in tanks on scales resting on the suction tanks and the time of weighing and time of passing a mark in the suction tank were taken. The scales were found to agree by weighing water in one and then running it into the other.

The boilers are connected to the same flue and steam main and each has an Eynon & Evans steam jet blower in the ash pit, but this was only used in the test of Oct. 16. This attempt to get over 500 HP. out of the boilers by use of the blowers resulted in showing that the blowers hurt the soft-coal fire rather than helped it.

The Sept. 1 test shows the unreliability of short tests, since the Parker boiler showed an impossible advantage. On the other hand the Parker boiler got the worst of it in the Sept. 30 test, owing to a badly-clinkered grate. All the firemen complained about it and did not seem to be able to handle the fire in the usual way. Comparing this test with that of Sept. 17, it will be seen that the Babcock & Wilcox used more coal, while the Parker fell off 2,500 lbs. The firemen were unable to dislodge the clinker during the test without keeping the fire doors open for an excessive period, so the best was made of a bad job.

On the 20th day of the 30-day run a defective expanded joint in the Parker boiler gave out and the boiler had to be shut down. The tube end had not been run past the shoulder in the box. The tube was pulled back into the box by running a length of pipe through it and screwing up on a flange at each end.

On the 29th day of the run a tube was found blistered in the Babcock & Wilcox boiler, and it had to be shut down and a new tube put in. The clinker was chipped off the grate and this was the cause of the good showing in the Sept. 30 test. At the end of this test it was discovered that two more tubes were blistered in the Babcock & Wilcox boiler and had been leaking during the test.

It was assumed that the leakage did not measurably swell the apparent evaporation of the boiler since it had shown about the same results in the test of Sept. 17.

The Parker boiler was shut down on Oct. 9 and opened up in the presence of City Inspector Madden and representatives from the Baldwin Locomotive Works, the United Gas Improvement Co., the Penna. R. R. Co., the Edison Illuminating companies and Mr. Francis Head for the Traction Co. Mr. Madden pronounced the tubes clean, although it was evident that scale had been formed in the bottom row as scattering patches of it could be seen and 186 lbs. of it in small pieces was found in the front ends of the drums. About 4 ins. depth of mud was found in the water drums, while the steam drum was clean except for 33 lbs. of larger pieces of clean scale retained at the front end by the screen.

The valves in the top boxes of each element were found clean and in perfect working condition.

The scale appears to form entirely in the bottom tubes, and as soon as it attains any body peels off and is swept out of the tubes and thrown up into the drums by the force of the flow, exactly the same as in the Parker boiler at the Roach shipyard, Chester, Pa., which has been running now for two years and a half without any cleaning of the tubes except by the boiler itself. The mud is found to settle toward the middle of the water drums and an angle has been placed over the drum blow-offs so that the mud is now blown out very efficiently.

The price of coal at the time of the tests being abnormal, $3 per ton was agreed upon as a fair basis for computation for bituminous coal at the fire doors. On this basis the saving shown by the Parker boiler over the Babcock & Wilcox computed according to contract was as follows: Sept. 1, $6,149; Sept. 2, $2,224; Sept. 17, $2,863; Sept. 25, $3,765; Sept. 30, $1,829; Oct. 16, $2,534.

It was understood, of course, that to get this saving the boiler must be run at full power for the full time.

As the lowest figures were far above the limit of the bonus and all the other claims were conceded, the company paid the Parker Engine Co. the full amount of the bonus on Oct. 10.

The test of Oct. 16 was run to see what the boilers would stand without injury, but the blowers failed to add to the power, and this test fell far short of the results on Sept. 17, when the average for one of the eight-hour shifts ran up to 470 HP. on the Parker boiler.

We suggested to President Wells of the Babcock Co. that they send a representative to witness the tests, but his statement was that he knew what his boiler would do and only wanted to know what ours would do.

The company was not able to shut down the Babcock & Wilcox boiler for inspection until the past week, when a scraper was run through the two lower rows of tubes. The bottom row of tubes in this boiler were renewed about a month after the Parker boiler was started, so that those tubes have run about as long as the Parker tubes. We were not present when the scraper was run through, but the new tubes appear to have a solid coating of scale all around with no indication of peeling off as in the Parker boiler. The man in charge of the boiler cleaning thinks that the scale is thicker than in the Parker boiler, but we are of the opinion that it is about the same. The only way to tell would be to bore out the tubes, which cannot be done at present. We judge that the scale forms about as rapidly in the bottom tubes of the Parker as in the Babcock, but why it peels off in one and not the other is a difficult question to answer unless it is the extraordinary force of the flow in the Parker tubes.

The accompanying table gives the results of the tests. The heating surface of the two boilers tested was as follows:

	B. & W.	Parker
Heating surface in tubes, sq. ft.	3,761	3,[illegible]
" " " drums " "	314	2[illegible]
" " Total " "	4,075	4,1[illegible]
Grate surface " "	66.5	[illegible]

The samples of scale taken from the Parker boiler, submitted to us with the above letter, are all about 1-16-in. in thickness. Why the scale should flake off in this boiler after reaching this thickness and not continue to accumulate, as happens in other types of water-tube boilers, is a difficult question to answer. Apparently the only reason that can be found is the velocity of circulation through the lower tubes, which is very much in excess of that in any other design of water-tube boiler which we now recall.

The question whether circulation does or does not prevent the formation of scale is one upon which engineers are by no means agreed. From the best information we can obtain, rapid circulation is most effective in preventing mud and sediment in the water from baking onto the plates, and it is least effective in the case of hard waters, particularly those containing calcium sulphate. It is fair to say that the scale from the Parker boiler appears to be a lime scale, and not composed of sediment.

Besides the boiler at the Traction power house, the Parker Co. has had a boiler running at the Roach shipyard for 2½ years, which we are informed has never had a single tube cleaned or renewed. Tests of this boiler by Prof. Spangler, of the University of Pennsylvania, were reported in our issue of Aug. 22, 1901. A Parker boiler of 100 HP. has also been installed at the Michigan College of Mines, at Houghton, Mich., and the theory of the boiler was discussed by Prof. O. P. Hood, of this institution, in a paper recently read before the Copper Country Engineering Society. As the matter is of much interest to steam engineers, we reprint below a portion of Prof. Hood's paper:

The principle of bringing the hottest gases in contact with the hottest state of the material to be heated, and as the temperatures of the gases fall, let them meet cooler and cooler material, has been adopted in many heating operations. Illustrations of the principle are found in the modern cement roaster, the blast furnace, and the lime-kiln; also in feed-water heaters and condensers.

Why do we not find it broadly applied in boiler design? So little attention does this principle receive at present that little mention of it is now made in texts, much more thought being given to keeping all parts of the boiler at the same temperature rather than at continually increasing temperatures from the point of introducing the feed water to the point of steam generation.

The very real trouble experienced in a boiler of rigid construction because of diverse temperatures in different parts has seemed to divert attention from the possible gain to be had by following the principle stated. To follow this principle logically we should have a boiler which at one point would be at the temperature of feed water and in contact with the flue gases at their coolest.

TABLE SHOWING RESULTS OF TESTS OF A BABCOCK & WILCOX AND A PARKER STEAM BOILER AT THE POWER HOUSE OF THE PHILADELPHIA RAPID TRANSIT CO., 13TH AND MT. VERNON, STS., PHILADELPHIA.

Items.	Test—No. 1; Sept. 1 B. & W.	No. 1; Sept. 1 Parker.	No. 2; Sept. 2 B. & W.	No. 2; Sept. 2 Parker.	No. 3; Sept. 17-18. B. & W.	No. 3; Sept. 17-18. Parker.	No. 4; Sept. 25-26. B. & W.	No. 4; Sept. 25-26. Parker.	No. 5; Sept. 30-Oct. 1. B. & W.	No. 5; Sept. 30-Oct. 1. Parker.	No. 6; Oct. 16-17. B. & W.	No. 6; Oct. 16-17. Parker.
Duration of test, hours and minutes	6:49	6:30	12	12	24	24	24	24	24	24	24	24
Average steam pressure by gage (corrected), lbs.	142.15	142.15	140.8	140.8	143	143	142.14	142.14	142.8	142.8	142.0	142.0
" draft in flue, ins. of water	.76	.76	.658	.675	.77	.77	.5	.75	.76	.76	.75	.75
" draft above grates, ins. of water	.544	.464	.533	.408	.62	.50	.60	.50	.60	.52	.59	.50
" temperatures of escaping gases	614.0	410.5	509.9	414.5	536.5	442.8	576	448	575	443	556	448
" temperatures of feed water	80.4	80.4	81.65	81.65	71.0	71.0	72	72	68	68	61	61
Total coal consumed, lbs.	8,306	6,621	14,190	14,775	36,000	37,000	34,000	35,250	36,500	34,500	31,303	35,058
Moisture in coal, lbs.	Dry.	Dry.	Dry.	Dry.	4%	4%	4.5%	4.5%	4%	4%	3.5%	3.5%
Total dry coal, lbs.	8,306	6,621	14,190	14,775	34,560	35,552	32,470	33,664	35,040	33,120	30,207	33,831
Refuse in coal, lbs.	11.7%	11.7%	12%	12%	13%	13%	13.3%	13.3%	13.3%	13.3%	13.3%	13.3%
Total combustible, lbs.	7,334	5,846	12,487	13,002	30,067	30,930	28,152	29,187	30,374	28,715	26,190	29,331
Dry coal per hour, lbs.	1,218.5	1,018.6	1,182.5	1,231.0	1,440.0	1,460.0	1,353.0	1,402.67	1,460.0	1,380.0	1,258.6	1,409.6
Steam, percentage of moisture	.40%	.22%	.62%	.33%	.40%	.26%	.48%	.25%	.39%	.24%	.59%	.28%
Water from separator per hour	.....	.....	.....	.....	.....	.....	36.04	24.1	35.74	30.9	37.78	28.0
Total water pumped into boiler, lbs.	62,721	60,936	111,282	125,369	280,893	312,811	254,138	293,763	283,300	281,563	231,990	281,659
Equivalent evaporation, from and at 212° F.	74,261	72,148	131,647	148,311	335,386	373,496	303,187	350,459	339,110	337,031	279,316	339,117
Equivalent evaporation from and at 212° F., per hour	10,894	11,099	10,970	12,359	13,974	15,562	12,633	14,602	14,130	14,043	11,638	14,129
Economic results: Water actually evaporated per lb. of dry coal	8.55	9.20	7.84	8.48	8.12	8.79	7.83	8.73	8.08	8.50	7.68	8.32
Equivalent water evaporated per lb. of dry coal from and at 212° F.	8.94	10.89	9.28	10.04	9.70	10.50	9.34	10.41	9.67	10.18	9.25	10.02
Equivalent water evaporated per lb. of combustible, from and at 212° F.	10.12	12.34	10.54	11.41	11.15	12.07	10.77	12.01	11.16	11.74	10.66	11.56
Percentage of gain	.....	21.8%	.....	8.2%	.....	8.25%	.....	11.5%	.....	5.2%	.....	8.4%
Dry coal per sq. ft. of grate per hour	18.3	15.3	17.78	18.51	21.65	22.25	20.34	21.00	21.95	20.75	18.93	21.20
Water evaporated, from and at 212° F., per sq. ft. of heating surface, per hour	2.67	2.65	2.69	2.94	3.43	3.71	3.10	3.48	3.46	3.35	2.86	3.37
Horse-power (34.5 lbs. water from and at 212° F. pr hr.)	315.77	321.73	318.0	358.0	405.0	451.0	366.0	423.0	409.5	407.0	337.34	409.53
Heating surface per HP.	12.90	13.08	12.81	11.71	10.06	9.29	11.13	9.91	9.95	10.00	12.08	10.24
Horse-power per sq. ft. of grate	4.75	4.84	4.78	5.38	6.09	6.78	5.50	6.36	6.16	6.12	5.07	6.16

From this point to the region of greatest heat there should be a continual increa e in temperature of the water and the boiler, reaching the temperature of the steam over the furnace. Only so much feed water should be put in at one end as shall be evaporated by one pass through the boiler.

Belleville, in France, built a boiler consisting of a continuous coil of vertical tubes connected with return bends, the feed being at the end farthest from the fire and steam generated in tubes next the furnace. The feed was dependent on pumps and every return bend formed a pocket and trap, two things which make clear the record of failure. Herreshoff, in America, attempted to follow this principle, using a pump to maintain circulation, but also recorded a failure.

A step in the right direction is made in modern practice when in a supplementary device added to the boiler a lower average temperature may be presented to the departing gases. This is the stack-feed heater or economizer. From the rear to the front of the economizer there should be a general increase in temperature. Throughout the boiler, however, a nearly uniform temperature is presented.

Where the services of the oconomizer shall end and the function of the boiler begin is purely a matter of proportion and convenience, for the heating of water certainly presents no demand for two kinds of apparatus so widely differing in form. The addition of a superheater over the fire would take still another step in the right direction.

It does not seem a sufficient trial of the principle, however, to divide the heating operation into two or perhaps three steps and place these steps in proper order. There should be some simple device, of similar form throughout filling satisfactorily the offices now apportioned between the stack-feed heater, the boiler and the superheater.

A graphical representation of the process of heat absorption may aid in presenting the principle.

Suppose we have 100 rectangular boxes without tops a foot square, and so placed on a non-conducting setting that the bottoms of the boxes form the top of a flue 100 ft. long. We have then a series of evaporating pans forming 100 sq. ft. of heating surface, as near like good boiler heating surface as we can get.

Introduce (at one end into the flue) gases at a temperature of 2,000° F., and an incandescent bed of coals to radiate heat to the first few feet. If we attempt to compute the amount of water likely to be evaporated from each succeeding pan, we find we have a problem not at all simple and one in which a much larger amount of guessing than figuring must be done. We wish to find at what rate gases give up heat as they proceed along the heating surface.

In dealing with medium temperatures as in condensers, feed-water heaters, steam and hot-water heating apparatus, it is usually assumed that the loss of heat is proportional to the difference in temperature of the bodies exchanging heat. That this is not strictly true is readily shown by rapidly stirring the water in one of our pans. We would find that the evaporation was increased with the rapidity of motion of the water. Evidently the vigor of circulation of either of the fluids in contact with the heated plate is a factor in determining the rate of cooling of the gases. This is so true that the statement has been made that the heat absorbed is proportional to the velocity of flow of the fluid over the metal. It is well known that in blowing air over heated coils the amount of heat absorbed per degree difference increases very rapidly with an increased velocity of air.

It has been so desirable to possess knowledge as to the rate of cooling of gases in a boiler that numerous experiments in subdividing actual boilers have been tried

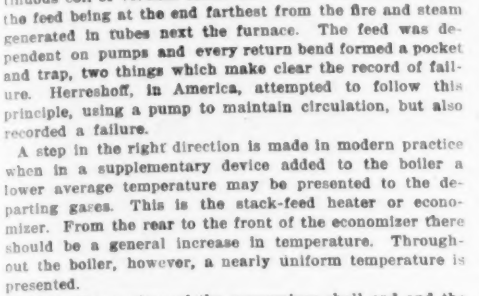


Diagram Illustrating Transfer of Heat from Gases to Water in a Steam Boiler.

with very interesting results, but under such circumstances as to lessen their value because of incomplete observations. It is however known positively that a foot of heating surface exposed to a large temperature difference is worth more per degree difference than where the temperature rise is smaller. Just how much more cannot be stated with accuracy.

I have plotted the results of a number of experiments and the curve shown herewith is a little more likely to agree with the facts than any other I know how to draw at present. Let the base line OX represent our 100 ft. of heating surface with the gases flowing from O to X. The vertical distance to the curve T T' represents the temperature of the gases at any point on the line O X. The curve starting from a temperature of 2,000° drops 700° in passing 12 to 15 ft. of heating surface and loses a like amount in passing the remaining 85 ft.

The evaporation in any pan in our problem would be about proportional to the fall in temperature of the gases in passing that pan. This probable evaporation is shown by the line E E' in which distance above O X represent the rate of evaporation at the several points. If the pans be replaced by a closed boiler and steam raised to a pressure of 125 lbs., the temperature of the water, 352°, would be represented by the line A B.

The relation of the curve T T' to the line A D represents the temperature differences in the usual boiler. In order to lower the final temperature, T' recourse is had to a stack-feed water heater or economizer which can present a lower average temperature to the gases than can the boiler. It is evident that the heating surface in these last few feet of boiler surface could readily absorb much more heat were the temperature difference only greater. The rate of absorption of heat as shown by the inclination of the curve at the latter part of the boiler is very low, so low in fact that it ought and can be made to do the work of the economizer by making at this point a greater temperature range.

In generating steam at 125 lbs. pressure from feed water at 62° about 25% of the total heat required is needed before steam temperature is reached. From our diagram showing evaporation we find that about the last two-thirds of the heating surface is needed to do one-fourth of the total work of heating. If we could introduce water at 62° at the last foot of heating surface and reach steam temperature at about four-tenths of the length from the furnace, the temperature line of the boiler would be A c d instead of A B, being lowered at the rear of the boiler 290°. This would certainly lower the curve T T' from the point (w).

To predict just how much it could be lowered we could look at the problem in a number of ways. Expecting the boiler to give the results of an economizer from the point c to d, we could predict a drop in flue temperature of 435° from the temperature at c, which is about 900°. The terminal flue temperature would therefore be 465° instead of 600°; that is a drop of 135°.

The drop in flue temperature should be greater than this, because the temperature difference at c is much greater than an economizer usually has to deal with.

Another way of looking at the problem would be to consider that as the heating surface from c to B had been able to reduce the temperature T^1 to within 248° of the boiler it should do nearly as well when the boiler was colder. This would call for a terminal temperature of 310°. Somewhere between these two extremes of 310° and 465° the true temperature would lie. From actual running of such a boiler I find the flue temperature to run from an average of 360° to a maximum of 400°.

The line showing drop in temperature has been drawn to the 400° point. It seems evident that whatever the law of cooling assumed from T to T', the argument would apply with the same result, and that increased efficiency could be expected. The results from a boiler arranged in this way should equal what is now obtained from the combination of boiler and economizer.

It seems reasonable also to expect the present heating surface of the boiler to be enough more efficient in some of its parts to do the work of the economizer, without the addition of more surface.

That practical difficulties have been met with in boilers where even moderate differences of temperature existed in various parts of a rigid construction, should not obscure the principle here discussed, but should direct attention to some form flexible enough to stand such differences, rather than to demand that uniform temperatures should be maintained throughout a boiler.

THE PROPER OPERATION OF SEWAGE PURIFICATION PLANTS.

A paper with the title given above, by Mr. John W. Alvord,* M. Am. Soc. C. E., was scheduled for the meeting of the American Society of Municipal Improvements last October, but its author not being able to present it then leave was given to have it included in the Proceedings without having been read. We have just received a copy of the paper from Mr. Alvord.

Some of the difficulties under which the art of sewage purification labors, the author says, before passing to a review of lessons drawn from his own experience, are: (1) Financial embarrassments, due to the unpopularity of expenditures for this purpose, and the fact that the burden increases rather than decreases from year to year. (2) The physical unattractiveness of purification works, especially where, as is so commonly the case, they are neglected. (3) The termination of expert supervision after the constructing engineer finishes a plant. Instead the engineer "should be retained to supervise its operation for at least a year after it is started." (4) The tendency to overconfidence among engineers as well as the authorities in charge of operation, the plant frequently being declared a success after it has been in use a few weeks, whereas:

A plant should be a year old before it is valuable from the standpoint of operation. Two years' operation ought to enable one to form an opinion of it, and three years ought to decide its merits if carefully worked all that time.

(5) The last difficulty named is proprietary claims, on account of which engineers encounter much opposition, if not being

easy to convince city officials that sewage purification is a matter where thoughtful study and constant care in operation will tell in the long run better than the acceptance of a proposition from a strongly financed company guaranteeing operation to certain standards for a given length of time.

Mr. Alvord says that, as Mr. Leonard Metcalf has shown (Trans. Am. Soc. C. E., vol. XLVI., p. 456), "there is no patent" on the art of sewage purification "that is particularly useful or valuable."

The balance of the paper we give nearly in full:

THE SEPTIC TANK.

It is assumed for the most part that the septic tank once installed needs no particular supervision; that it operates wholly without attention, save, perhaps, a yearly cleaning. Now, it has been well demonstrated that this is not true; that the septic process is like all sewage processes, a sensitive and delicate process, amenable to control, and subject to natural fluctuations, which must be watched and governed if the best results are to be expected.

The compartment system of control, original with the writer, allows the operator of a plant to adjust the fermentation period of the sewage to its quality, the temperature of the weather, and the volume of flow, regardless of the total capacity of the tank. This is accomplished by dividing the tank into a number of compartments of unequal size, opening into each other by troughs and gates, so that one, two, three or more may be combined together as may be desired. Thus, if a large tank has been constructed for large future requirements, and the early sewage reaching the plant is small in quantity and weak in quality, indicating the desirability of a brief rest period in the tank, enough compartments may be cut out to produce the desired result.

The colder temperature of winter invariably lengthens the fermentation period, and in such cases an added compartment may be thrown into use to lengthen the time of fermentation. A thick and concentrated sewage requires a longer fermentation period than a thin and dilute one. An increasing flow of sewage, due to growth of the city or increased number of connections, may be provided for accordingly by the use of an increased number of compartments.

EVIDENCE OF PROPER REGULATION.—An effluent which is producing a marked odor of sulphuretted hydrogen has usually been too long within the septic tank, and as is well known, is a difficult effluent to treat in the second or anaerobic stages. It has been clearly shown by competent authorities that the nitrification of such effluents is exceedingly difficult or impossible, and the theory is advanced that the anaerobic bacteria have created toxins inimical to their own life and activity. A septic tank whose effluent shows advanced decomposition is plainly too large for the quantity then happening to flow through it, and the best results cannot be expected or obtained in the further or secondary treatment of the impurities. On the other hand, an effluent from the septic tank containing large quantities of suspended matter suggests that there is not a proper length of fermentation period to break down the suspended particles, and that additional fermentation is necessary. The writer has frequently observed the addition or deduction of a compartment to show a distinct and marked influence on the suspended matter coming over from the septic tank.

Some septic tanks are subject to the fault that the sewage enters them in such a way that it evidently traces a path through the center, so that the stay of the liquid and its accompannying particles of matter is not well averaged in its relation to the total capacity. This difficulty can only be obviated by modifications in design which will more evenly distribute the incoming sewage on the entering side. By the experimental use of coloring matter it has been observed that great improvements may be made in evening the flow by multiplying the number of inlets and carefully arranging that the liquid shall be as evenly divided between them as possible, thus avoiding the difficulty of having a certain quantity pass through the tank in a fourth or third of the time denoted by the ratio of the capacity to the entering volume.

EFFECTS OF PROPER REGULATION.—The proper regulation of the septic tank is of great importance, not only because it produces high efficiency for the tank itself, but because it also enables the secondary stages (filter beds—Ed.) to be operated with equally high efficiency. The ideal septic tank effluent is one in which the organic

*Hartford Building, Chicago.

matters in suspension have been resolved into the constitutent gases or dissolved in solution, and in which no suspended matter is present or no serious decomposition observable. This result is usually obtained with average domestic sewage in this country, with from four to eight hours rest or fermentation periods, that is to say, the ratio of the volume of entering sewage to the liquid capacity of such portion of the tank as is in use is such that theoretically it would follow that the entire contents of the tank would be changed in a given length of time. This is not actually the case, nor indeed is it practically necessary. Some particles of suspended matter may from various causes be detained in the tank many days, while others are hurried on to the outlet.

But nevertheless there seems to be to all practical intents and purposes a governing relation by the use of some such ratio as this, which, if watched and regulated, is an index to the proper management of the tank. Where septic tanks are followed by intermittent filtration, proper regulation of this character insures a minimum of labor in looking after and raking off the beds, and it is also observable from actual experience that such tanks properly run do not accumulate sludge to any considerable extent on their bottom, or an undue thickness of scum at the top. Of the 17 tanks which the writer has so far installed and watched, in some cases over four years, only one has had to be cleaned so far, and in this case the occurrence was due to an only partial familiarity with this principle, since satisfactorily demonstrated.

THE FALLACIES OF ANALYSIS.—Contrary to the usually accepted opinion, the proper operation of sewage purification plants does not at all require that analyses be taken in order to understand and govern operation. There are many signs by which one may judge of the efficiency of a plant without resorting to the tedious and delicate work of the chemist or bacteriologist. For instance, flaky black matter in the effluent is an evidence of more or less completed decomposition, and quantities of white humus are likewise indications of insufficient anaerobic bacteriological action. Ordinarily in plants which are not imperilling a neighboring water supply it is thought sufficient if secondary decomposition be prevented. This is easily demonstrated by sealing a small quantity of sewage in a bottle and letting it stand for two or three days. The appearance of black flakes by this time denotes that the impurities in solution were not by any means removed from the effluent by the action of the plant, while on the other hand, the non-appearance of such black ash and the absence of any odor of ammonia when the bottle is uncorked would ordinarily denote very good work on the part of the plant entirely sufficient in all ordinary practice. Analyses are so often misleading in sewage purification work, especially when published for advertising purposes, that one may well grow weary of being influenced by them, and among those whose knowledge of the subject is slight or superficial, widespread misrepresentation often results. If one were shown several buttercups, and informed that they came from a distant meadow which he had not seen, he would hardly venture the opinion that the whole field grew buttercups all the year round. Yet some of our sanitary engineers and chemists will take a few samples of an effluent and build up a whole theory of the percentage of purification which the plant is doing, generally leaving it to be inferred that this remarkable result is proceeding year in and year out.

PERCENTAGES.—Another of the fallacies which often deceive the student of sewage purification work is the determination of the results from any given plant in percentages of organic matter removed. It is comparatively an easy matter to obtain large percentages of removal from a strongly concentrated sewage, while it is an exceedingly difficult matter to obtain such a like large percentage from a very thin, weak or very dilute sewage. Therefore, it may be possible that the removal of 80% of organic matter from a very slightly polluted water may produce an effluent which is relatively much purer than the effluent from the plant removing the 99.99% of organic matter from a very thick concentrated sewage. It is, therefore, always necessary to know the relative strength of the original sewage before deciding from percentage figures that a plant is doing very high-class service.

CONTACT BEDS.

Arbitrary lengths of time for the sewage to remain in contact with the grain of the contact filter is not in accordance with what we know of the fluctuations in the character of the sewage. The fineness of the grain of the filter, the character of the liquid to be treated, the amount and fineness of the suspended matter which it carries, the temperature of the air and of the sewage, all must reasonably be expected to have some bearing on the length of time which the sewage is kept in contact, and yet almost every automatic device now available fixes the time of contact by the quantity of inflow. The rate of inflow may, and usually does, vary with wide limits, and in a way which may be quite different from the operator's ideas of the correct contact period required. Indeed, as usually operated, there is no chance at all for experiment as to what the correct contact period should be in any particular case. It is as evident here as it is with the septic tank, that if the proper and most efficient contact period for any given strength of sewage, temperature of air or liquid, and fineness of grain could be experimentally determined, the efficiency of the plant might be largely increased. There is room for great improvement over present methods of control.

LEAKAGE.—A slight leakage of the valves of the automatic device, or of the contact bed itself, is generally sufficient to greatly retard the contact period, and even altogether defeat the operation of the beds. An engineer cannot be too careful in superintending the construction to be certain that the contact bed is thoroughly watertight before putting in the contact material. The best form of automatic device for preventing leakage seems to be that which relies upon an air cushion for opening and shutting off the flow. Ordinary valves will often work either very stiffly after a while and finally stop the automatic device from working at all, or else will be so loose and leaky as to allow a large portion of the incoming flow to escape before the bed is filled.

SUPERVISION.—Much has been expected in the practical operation of sewage purification plants from the many automatic features which have recently been introduced. It has been thought that with the newer biolytic processes, supplemented by automatic devices for intermittent filtration or double contact work, little or no annual operating expenses would result. That this is true must not be denied, and that it does and will result in a more large adoption of sewage purification processes in the near future is certain. But no plant, however automatic it may be, however perfect its appliances for preventing manual labor, can be left alone, unless possibly one might except the small plants for household service. And yet it is quite remarkable how very generally this is the impression where automatic devices have been adopted.

INTERMITTENT FILTRATION.

In the operation of plants consisting of septic tank, followed by intermittent filtration as a second stage, great gains have been made by the introduction of automatic devices by which the effluent from the septic tank may be rotated on to the intermittent filtration beds. Such devices are operated by the falling sewage. This not only dispenses with the services of a man, who must divert the flow day by day, but makes the action of the beds much more regular and systematic, eliminating the contingencies of night, Sundays and holidays, which would naturally prevent uniformity in operation by hand. Then, too, the greatly lessened area of filter bed required for septic tank effluent means that there is the necessity for much more rapid diversion of the sewage from one bed to another than was formerly the case in intermittent filtration practice, and this almost puts it out of the question to employ manual labor for this purpose. Nowhere is the necessity for careful regulation of the septic tank more evident than it is in a plant of this character. If the septic tank effluent is filled with suspended matter, even finely divided, and the sand of the bed is of fine grain, very careful management is necessary.

NOTES ON PLANTS BUILT BY THE AUTHOR.

LAKE FOREST, ILL.—This plant, which has been under the supervision of the writer during the past year, consists of a septic tank of about 50,000 gallons capacity, divided into five compartments. The tank is neither light nor air tight. It has no patent arrangements for inlet or outlet, and is an open tank housed over with a light structure, giving ample ventilation and opportunity for inspection, while preventing the hot sun of summer or the cold winds of winter from varying the temperature of the sewage to any unusual degree. After leaving the septic tank the sewage passes into a dosing chamber holding 7,000 gallons of liquid, and by means of an automatic device operated by the falling liquid, it is delivered in rotation onto ten intermittent sand filter beds, consisting of the natural sand of the beach of Lake Michigan, as found in place. The beds are of 3,200 sq. ft. area each. At the present rate of flow these beds are working at the rate of 300,000 gallons per acre per day, their total area being ¾-acre. This sand is quite fine; 85% passing a sieve of 40 mesh, and 42% passing 60 mesh to the inch.

In practical operation it has been found that unless the septic tank was working at a maximum of efficiency, finely divided suspended matter coming over from the tank would, in the course of time, seal the surface of the filters and render it necessary to hand harrow them after the application of five or six doses. As each bed receives about two doses a day, this meant that the total area would have to be raked over twice a week.

In the early operation of the plant the man in charge, failing to rake the beds at all, reported that there must be something the matter with the underdrains, as the sewage would not go through the beds. A visit to the plant at once revealed that the difficulty was due to negligence, and a little application of the rake soon broke up the surface skin and put the beds in normal shape again. Later, after the septic tank was better regulated, much less suspended matter came over onto the filters, and a great improvement was seen in the amount of care which the beds had to receive. With fine sand used at this plant, it is probable that there will always be from 10 to 12 hours of labor per week necessary to keep the beds in good condition. The septic tank is now operating with 6½ hours' rest period, the longest of any of the plants under notice, the sewage being thick and concentrated. The tank has not been cleaned during the year, and no perceptible deposit has occurred.

WAUWATOSA, WIS.—The Wauwatosa plant is constructed on the same lines as the Lake Forest. A septic tank holding 40,000 gallons of sewage is operated on the five-compartment system; is constructed of concrete, and housed over with a plain brick house. The effluent is delivered to a dosing chamber, in a separate structure, containing about 6,000 gallons, which, by an automatic device, is delivered in rotation on to six filtration beds about 3¼ ft. in depth. The sand of which these beds are composed is much coarser than that used in the Lake Forest plant, consequently it has not needed so much attention. One hand harrowing each week for each bed has kept the plant up to its maximum efficiency. The effluent is clear and odorless after being kept in close-stoppered bottles for several days. The automatic device has been satisfactory, and has operated without stoppage for over a year. The tank is operated with about four hours' rest period, and, with the exception of removal of surface scum once or twice, has not needed cleaning. The filter beds are operating at the rate of 300,000 gallons per acre per day. When high water prevails in the river they are discontinued. The sewage is growing stronger. The plant has been in competent hands from the very beginning, and is excellently managed.

HOLLAND, MICH.—Two septic tanks here have been in operation over one year. The effluent is emptied into Black Lake. The sewage is not strong, as the sewer system is not yet extensive, but the tanks are exercising a marked improvement on the impurities, and so far have kept free from deposit. The main tank is constructed with three compartments, and has rest periods at present of about two hours. The plant is not closely watched.

GLEN VIEW, ILL.—This plant, originally constructed in 1898, has not been under the writer's observation for two years. One year it was entirely neglected. The last season it has had some attention. The septic tank is only a single compartment, and the secondary stage consists of contact beds of coke. The writer is informed that during the past season these contact beds have been successfully operated as continuous filters. About 10,000 gallons of very concentrated sewage a day is cared for. When the plant is supervised the effluent is good. The tank has had to be cleaned at least once every year, and one year (1899) it was cleaned four times.

DE KALB, ILL.—A septic tank of about 60,000 gallons capacity has been in operation since the middle of the summer. It is as yet too soon to speak of its effectiveness. It is not as yet followed by any secondary stage. It has not yet required cleaning.

PRINCETON, ILL.—A 60,000-gallon septic tank has been in operation about one year. It is built on the five-compartment system, and housed over. It does not receive special attention, but good results are reported. If so, they are probably accidental. It has never been cleaned, but some deposit on the bottom is reported. The rest period is not known. The plant was designed with intermittent filtration as a secondary stage, but the city is now hoping that the first stage will be sufficient to avoid nuisance. It remains to be seen if this hope will be realized.

DANVILLE, KY.—Three septic tanks have been in operation here over one year. The largest is 40,000-gallons capacity, and is followed by intermittent subsoil filtration. It is reported to be working well, but receives no special attention. It is, perhaps, too early to draw conclusions concerning it. It has not required cleaning as yet.

HIGHLAND PARK, ILL.—A small septic tank has been in operation on the west district for two years. It has received no attention whatever, and has caused no complaint as yet. It has never been cleaned. It is said not to be unduly filled with deposit. The effluent is reported as good, but the sewage it receives is not strong. It is noticed, as a matter of experience, that weak or thin sewage is not generally exacting in its treatment.

CONCLUSION.

The above data on some of the larger plants recently put into operation shows how little the majority of such plants are cared for after installation. If they avoid being obnoxious, it is often through their good fortune, and if they do become nuisances it is often no argument that they may not be properly designed. That this state of affairs is discouraging must be admitted, but with the over-confidence that has come in the newer biolytic process, it would seem to be inevitable.

The sanitary engineer working in the line of sewage purification must, for some years to come, as he has in the past, educate his public up to a just appreciation of the state of his art. It is a tedious and thankless process in many respects, but the revolution in the art in the past few years, and the great possibilities of sewage purification for the future, entails this responsibility upon him. The only thing to be done is to keep prominently before the public the enormous possibilities for civic cleanliness in this line of work.